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ON TELEPHONE SYSTEMS.

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[*A Lecture delivered before the* FRANKLIN INSTITUTE, *Friday, December 11, 1885.*]

Mr. President and Members of the FRANKLIN INSTITUTE:—The subject of the telephone is not so old as some other subjects that might be named, but within the past ten years it has engrossed so much attention in the way of experiment in all civilized countries, and has been the text for so many discourses that it is hard to find anything that shall be new to such a body of listeners as I have before me. I cannot hope to add to your knowledge, and my aim will therefore be to summarize the principles that underlie telephony, and the methods that have been adopted in developing it.

I would first remark that when any physical end is to be reached, there are certain physical conditions which must be recognized, viz., the laws of matter and of energy. There can be nothing accomplished in the physical world without it. Matter always is subject to its own laws, and the relations of matter to energy are such that no transformation of the latter ever takes

place except through the agency of matter. Indeed, it would be true to say that the body of physical science is made up of statements of the conditions under which energy is transformed.

We may call these the laws of nature; they are the conditions under which we live and to which we must conform, for a physical law can never be traversed. A balloon rises in the air not in spite of gravity, but on account of gravity. The pressure of steam is due to molecular impact, and if the molecular velocity be great enough, the boiler bursts. If the railroad train is to be run fast there must be no short curves in the road, for Newton's first law threatens disaster to such a combination.

Physical relations or laws then are fundamental, and every working machine works in accordance with them, whether the maker understood those laws or had them in mind or not. In the days when the commonly held theory of heat was what is now known as the Caloric theory, the steam engine worked just as it does now, and the development of the kinetic theory of gases, and a clearer understanding of heat phenomena has not affected the motion of a single molecule. Clearly then individual *intention* has nothing to do with physical laws involved in any piece of mechanism.

All mechanical devices embodying energy are either transformers, transferrers or governors. A furnace is a *transformer* of the chemism of coal and oxygen into heat. The boiler is a transferrer of heat to the water endowing it with greater molecular energy. The engine is a transformer of the heat energy into visible mechanical rectillinean and rotary motions, while the main shaft is again a transferrer of rotary energy to the distant room where, through the agency of pulleys and belts the transformations are chiefly such as change the character or direction of motion, converting rotary into reciprocating motion, or *vice-versa*, etc. In like manner a galvanic battery is a transformer of the energy of zinc and acids with electrical energy. The leading wires are transferrers, conducting the electrical energy where it is needed, while the relay or sounder is again a transformer of the electrical energy into mechanical motions of an armature which may record its own movements, or the latter may be interpreted at once by an experienced listener. If a Morse key be put in such a circuit, it is as a controller of the transformations, and of course of the transference as well. It neither adds to nor subtracts from the energy, it simply

controls it. So long as the Morse key is manipulated by hand, the electric energy available is subject to the will of the operator, only however in its *rate of delivery*, not as to its generation, its velocity of transmission or its transformations in the sounder. Those are the physical relations which are beyond the reach of any intention, and could not be changed by any will or wish the manipulator might have.

It is, however, possible to make an automatic governor or key which shall so control the electricity as to produce a set of signals similar to those made by hand, but this automatic device is built upon physical principles, has its own laws of working, and, *while it is working*, is not subject to any one's dictation or will or wish. If it does its work properly it is because it is made in accordance with the laws of matter and of energy, which are concerned in its working, whether the maker knew all those laws or not. It is as true for such a piece of mechanism as for a boiler injector or the governor of a steam engine. These principles or laws are simply *adopted*, not adapted; the mechanism is always *adapted* to the principles or physical laws which are to be operative, and it is right that the distinction between physical laws and the apparatus through which transformations of energy or the control of energy, are possible, should not be lost sight of, for I have known where the statement of the recognition of a physical law in the sense in which I have described it, has been made as a claim upon the physical law itself. The law has allowed it, and the court has awarded it.

What, then, are the physical conditions which underlie the electric transmission of speech? Speech,—articulate speech—consists of sound vibrations in the air, generally of a highly complex character. The sounds themselves are partly arbitrary and partly automatic; that is, what I call a tree a Frenchman would call *l'arbre*, and a Chinaman something else. So much is purely arbitrary, but there is a difference,—a physical difference between my word tree and your word tree, which no amount of pains taking on my part could make identical, the character of my voice is not subject to volition; it is as automatic as the sound of a violin or of a cornet, and that for the reason that the instrument that produces it is a physical instrument, having its own laws of vibration and resonance. The pitch may he varied, but not the quality, and so

it is for a cornet or a violin. Articulate sounds are the arbitrary ones, and have no particular character like musical instruments, no particular series of harmonics belongs to speech, but articulate sound vibrations in air involve *energy*, and can only be maintained by the expenditure of energy and any question of the transference of such vibrations from one point to another, is simply a question of energy. If the distance be not too great, there may be enough energy in the vibrations in air to affect the auditory nerve of a listener, and no transformation will be needed. If the sound-waves are prevented by a tube from spreading spherically in space, the energy will not be so wasted and the sounds be heard at a greater distance, but there is a limit there, and if speech is to be rendered at a greater distance, apparatus for transformation and transference must be employed. If electricity is to be used, then the relations, if any, between sound vibrations and electrical phenomena must be employed. We might be supposed to know that electricity quickly distributes itself in a metallic circuit, and also that a Morse key enables one to send electric pulses at will through an electric circuit. But a key that will respond to sound vibrations *must necessarily be automatic*, for no hand can move with the rapidity and variety of sound vibrations. When sound vibrations fall upon any surface they impart a portion of their energy to it, and cause it to vibrate in a similar way. One may whisper close to a closed door, and be heard by one whose ear is against the other side of the door. The smaller and thinner the surface against which such sound-waves spend themselves, the greater will be the amplitude of the movements. Let such a surface, capable of responding to any sound vibration, be provided with freely moving electric terminals, so that every vibration shall send into the wire a corresponding electric impulse or wave, and we have a device that will do for speech in an automatic way what the Morse key will do when manipulated by hand, namely, vary the strength of an electric current in the circuit in accordance with certain arbitrarily chosen symbols. Such a device is now generally called a transmitter, but in reality it is an automatic governor, as its function is to control an electric current operated by the variable energy of sound-waves. So far as the apparatus described does what has been said, we have an electric circuit in which the electric energy is a variable quantity depending upon the vibratory movements of

the tympanum, and this may be from the maximum quantity which the provided conditions permit, to nothing if the current be entirely broken.

With the Morse key, this range is reached for each signal; with the other, the range cannot be so great without danger of omitting some of the vibrations that constitute the sound. The sound vibrations in the air are a series of continuous waves so long as the sound is being produced. If the velocity of sound in air be, say, 1,125 feet per second, and if a sound of any kind be produced for, say, one second, then the first wave will be 1,125 feet from the last wave, and between them will be an unbroken series of similar ones. If such a series had acted upon the terminals of the electric circuit, the same unbroken series of electric waves would have been produced.

WHAT IS A SYSTEM?

A system is a series of steps or processes employed to attain some end or accomplish some purpose. Some things may be done with a single movement, yet there are few things that may not be done in more than one way. A tree may be cut down with an axe, or sawn down either by hand, or by a circular saw run by steam, or it may be burned off by a platinum wire made red-hot by electricity, or it may be gnawed off by beavers.

If time is to be kept, it must be by some *uniform movement*, which may be secured by a pendulum or balance wheel, each in train with a set of gears and a weight or a spring. The end attained is the same, but the steps are different, and these may properly be referred to different systems or methods. Uniformity of action is the physical, necessary condition for time-keeping, but uniformity of action is not a method of time keeping.

If the early maker of a pendulum clock had said: "I have discovered that in order that time should be kept, it is necessary to have a uniform, mechanical movement, and I have invented a pendulum to effect this; I, therefore, claim the method of and the apparatus for time keeping;" if some patent office had granted such a patent, and if the courts had upheld the claim, the case would be paralleled by the celebrated fifth claim of the famous telephone patent of 1876. It might be true that no one had stated the condition so tersely before, yet the Clepsydra embodied the proposition and astronomers had predicted eclipses on the

basis of uniform motion for time keeping for thousands of years before.

Morse proposed a telegraphic system consisting of a battery, a key, a transferring wire, and an electro-magnet, with a movable armature, which should record its movements. Not one of the steps was original with him. He invented neither battery, nor key, nor conducting wire, nor electro-magnet, but he combined these in such a way as to produce valuable results, at distances which had not been reached before. Bain proposed a telegraph system, in which a battery, a key, a wire, and an electro-chemical instrument were employed. Neither of these steps did he invent. The differences were, briefly, that where Morse employed magnetism and its mechanical relations, Bain employed chemism and its optical relations. One embossed paper, the other made a blue mark upon it. But the differences were deeper than this, for the battery-power needed to do the work was much less in Bain's than in Morse's, and, moreover, there is a limit to the speed with which an armature of a magnet can move, and, therefore, a limit to its telegraphic speed, but there is no such limit to the speed of such chemical reactions. Indeed, the only reason I ever heard for the abandonment of Bain's system was its unnecessary delicacy. In each of these systems, the electricity which was to do work was fitted at the transmitting end for the work it was to do at the receiving end, and the movements, of whatever sort, at the receiving end, had corresponding motions of the key. Then there was the Dial system of telegraphy, wherein a finger moving round a dial caused a similar movement of a finger about a receiving dial. In each and all systems, it was recognized as a physical necessity that if electricity was to do a certain work, it must be fitted for it at the transmitting station. If dots and dashes are wanted, they must be made at the transmitting station. The wire is employed simply as a transferrer, not as a transformer, and if it has such a transforming property, its efficiency as a conductor is so much impaired, the amount of energy it can transmit in a given time is less, and the characteristics of the energy are more or less effaced.

It is not, then, singular to the telephone that the characteristics of the energy needed at the receiving end should be given to the electricity at the transmitting end, but on the contrary, it is the physical condition that underlies all electrical apparatus what-

ever and depends solely upon the laws of the transformation and conservation of energy, and must be conformed to, as any other laws must. To give a new crook to a magnet, or vary the relations of mechanical details in a transmitter, and call them a new system, is, to me, as ridiculous as it would be to paint the parts some different color and then christen it a new thing. That is not saying but that such changes may be improvements, but so long as the series of changes is precisely the same, from beginning to end, in both transmitter and receiver, I do not recognize the appropriateness of calling anything a new system. A different set of changes, involving different transformations of energy, different laws requiring different apparatus, I do call a different system, and these must belong to both transmitter and receiver.

In conformity to this, what are the possible ways by which sounds of any sort may be electrically transmitted and reproduced at another place?

(1.) As to the so-called transmitter, or the device for fitting the electric energy for the work it has to do. There are two ways in which electric energy in a given circuit may be controlled. (I) By varying the resistance, and (II), by varying the electro-motive force in it. If there be any third way, I do not know of it. If, then, the energy of sound-waves can be so utilized as to vary the resistance in an electric circuit in conformity with the varying phases of the sound-waves, we shall have one method, and as there is to be no transformation, it is evident that the action will be wholly mechanical, for the sound vibrations themselves are but mechanical movements in an elastic medium, and if there be no transformations, the last term of the series will be mechanical in the same sense.

If sound energy can be made to vary the electro-motive force in a circuit, without changing the resistance in the circuit, then we shall have another and a different kind of transmitter. The discovery of magneto-electricity make it possible, and some of the very first magneto-electric experiments pointed out the way, namely, the generation of electric cnrrents by means of the motion of the armature of a magnet.

(2.) As to receivers. The range of possible receivers is not restricted as is that of transmitters and a great number of ways of utilizing the electrical energy that has been properly adapted by

a transmitter have been devised. It will be well here to recall the various effects which electricity is competent to produce.

(I.) Electricity is competent to affect a magnet, which tends to set itself at right angles to the wire through which the current flows. Ordinary galvanometers are constructed to utilize this action of electricity.

(II.) Electricity is competent to produce a magnet, and upon this property the common electric telegraph and hundreds of other applications have been founded.

(III.) Electricity is competent to decompose compound chemical substances, as for instance, water; and for the utilization of this property of electricity, a common and simple one is the production of a blue mark by means of the decomposition of the ferro-cyanide of potassium as in Bain's electric telegraph.

(IV.) Electricity is competent to deposit one metal upon another metal, and from this property has grown up the great industry of electro-plating.

(V.) Electricity is competent to produce heat, the highest temperature which man is able to produce at present is that in an electric arc, and is used for the fusion of refractory substances, such as platinum, gold and steel.

(VI.) Electricity is competent to produce light, and the two systems of electric lighting, namely, that by the arc and that by incandescence, are developments of the possibilities in that direction.

(VII.) Electricity is competent to reduce the friction between bodies, and this property has been utilized by Edison in one of his telegraphic systems.

(VIII.) Electricity is competent to produce either heat or cold at a junction of metals, according as the current flows this way or that, which is known as Peltier's phenomenon.

(IX.) Electricity is competent to produce various physiological effects, and is extensively used as a therapeutic agent.

(X) Electricity is competent to give a tortional strain to a conductor through which it flows, either right handed or left handed, according as the current is towards or away from the observer. This has been used to measure the strength of the current flowing through the wire as a kind of galvanometer.

(XI.) Electricity is competent to produce very various gaseous

phenomena, and a visible motion of paddle-wheels, by the impact of gaseous molecules, as is exhibited in various forms of Crooke's tubes.

(XII.) Electricity is competent to twist a ray of light in air or other transparent medium, but this is at present used, so far as I know, only in the investigation of physical phenomena among molecules.

(XIII.) Electricity is competent to produce in the non-material substance, called ether, a certain condition, which is generally known as the electric field, a field within which various interesting phenomena are manifest, and which are at present the subject of investigation by physicists.

(XIV.) Electricity is competent to produce a noise or sound by disruptive discharge, as in the phenomena of thunder storms and on a small scale by electric machines and Leyden jars.

(XV.) Electricity is competent to produce attraction, but this phenomenon, which has been known perhaps longer than any other of an experimental electrical kind, has not been utilized to any considerable extent.

It is not improbable that there are other things which electricity will do, which I have not enumerated, or that will hereafter be discovered. It is possible to make nearly every one of these effects available in a telephonic receiver.

It is not my intention to undertake any settlement of historical matters in connection with the telephone, nor to enter upon any questions of priority, and the names which I shall employ to designate the different systems I describe, I only adopt for the sake of distinctions which exist, and these can be more easily kept in mind if so individualized, than in any other way.

Farrar, of Keene, N. H., discovered in 1851, by experiments with electro-magnets and vibrating reeds that completed and broke an electric circuit, that the magnet was capable of responding

FIG. 1.

simultaneously to several distinct series of such reed vibrations, and that suggested to him that if he could contrive to vary the electricity in the circuit by voice vibrations, as he did with the reed vibrations, that he could electrically transmit speech. He was not able to devise an appropriate transmitter, and was discouraged from the attempt by the expressed opinion of the impossibility of doing it by Prof. Silliman. He had, however, the receiver, and had proved its ability to act in the way proposed. I cannot allude to Farrar's system as complete, for the work was but half done, and I therefore put in the place of the transmitter the interrogation point, to indicate what was lacking.

REIS'S SYSTEM.

Nearly ten years after that, Reis, of Germany, invented the mechanism that Farrar lacked, namely, an apparatus that was capable of responding to the minutest shades of acoustic vibrations, and having an automatic attachment making part of an electric circuit, the motions of this attachment, or the electrodes, as it may be called, being governed altogether by the sound-waves in the air.

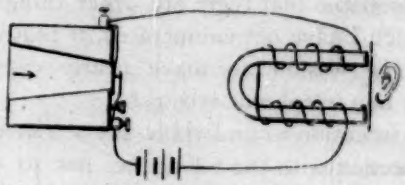


FIG. 2.

Reis made a number of transmitters, varying the mechanical details in each, but they all had in common a membrane stretched taut over an aperture, and against which sound-waves of any kind were to impinge. This membrane had fastened to its middle a thin strip or disc of platinum foil, which was connected by a wire to a binding post. Connected to another binding post was a metal strip reaching to the middle of the membrane, where a piece of platinum wire, fixed at right angles, was so adjusted by a screw as to touch gently upon the platinum disc and so complete the electric circuit with a battery, and an electro-magnet for a receiver. The energy of the sound-waves was employed to control the electric energy in the circuit, and it was expected that any change in the one would make a corresponding change in the other. That Reis

expected this, is perceived in his lecture, where he gives the curves for compound sound vibrations in air, a continuous and not a broken one, which, if it was to be transmitted and reproduced, must not have lost any of its characteristics. It is certain that he intended to have reproduced in his receiver all the characteristics of the sounds made at the transmitter. He explains the action of his transmitter as making and breaking the circuit for every vibration of the membrane, and a deal of wearisome talk has been made of late years about Reis's *intention*, one party declaring the intention to be in the function of the apparatus to transmit and reproduce sounds of all kinds with their characteristics, and they point to Reis's statement that he thus did transmit and reproduce the sounds of the piano, accordeon, clarionet, horn, organ pipes and speech. The other party declares that Reis's intention was to make and break the circuit for every vibration, and therefore he could not possibly have intentionally transmitted speech for a continuous circuit and an undulatory current are essential to do that. If, therefore, Reis did do what he says he did, it was accidentally done, and the apparatus was not working as it was intended to work. It ought to be remarked, that if the tones of the above-named instruments were reproduced, there must have been the same continuousness that is now insisted on as being essential for the transmission of speech, for the sound of a piano string is made up of a number of separate tones in harmonic series, and continuity is as much a characteristic of such sounds as of any other. But Reis distinctly says that he was able to transmit human speech, adding, "though not with distinctness sufficient for every one," which implies if anything that it was distinct enough for some. Reis explains the lack of distinctness to which he alluded as being due to the fact that the higher overtones were too weak in the receiver for all to hear, not that some of them were not present at all But that objection of a lack of distinctness was brought against the telephone of the present day. Over and over again, I have heard persons say when first listening to a telephone that was speaking well, that they couldn't hear what was said, and I dare say everyone has had a similar experience who has worked with telephones to any extent. The fact is, that nearly everyone requires some experience with a telephone before he can make out all that is said, and Reis's audience was not made up of experienced persons.

There is, however, no reason at all to doubt that Reis did transmit speech with his apparatus, for, as I have said before, the working of the transmitter is *automatic*, and depends upon the sound-waves that fall upon it, and not upon anyone's intention of how it shall do its work. Take any Reis transmitter and couple it in a circuit with a battery without anything for a receiver. Now, speak to the transmitter. Will the sound-waves vary the current strength in a proportional way? In other words, will the current be the kind known as undulatory, and one capable of reproducing the words spoken? There is only one answer to this question; there are no ifs nor buts about it. Whether they be heard or not, is another question depending upon the kind of device used for transforming the electric energy, and its degree of sensitivity, also, the acuteness of hearing of the one who listens. If an electro-magnet ill adapted to the conditions be used for a receiver, the speech might not be heard, but it would not be because the character of the work of the transmitter was at fault, but because the receiver was not delicate enough. To say otherwise, would be like denying the existence of a current of electricity in a circuit, because the needle of a galvanometer made for strong currents gave no indication of one. If it is of any importance to know whether there be a current or not, include in the circuit the most delicate galvanometer to be had. The test for the character of the working of the Reis transmitter is similar; put the most delicate receiver at hand in the circuit and listen. When such a test as that is applied, it is always found that the current from a Reis transmitter is identical with the one in common use to-day for telephonic purposes. Where this is done, however, the deniers of Reis's claim assert that the transmitter works on account of knowledge acquired since 1876, but they know better, and argue thus for commercial reasons only. Indeed, I think it proper to say here that I have conferred with a great number of electricians in various parts of the country about this matter, and there is the greatest unanimity concerning it, that Reis did invent a speaking telephone; that he used it for that purpose, and that it works in the same way as does the modern commercial telephone. A number have given me testimonials to that effect, and several who do not wish to be mixed in the controversy, express privately to me the same views precisely. The only ones that oppose it are those who have a pecuniary interest in denying it.

Reis's system of telephonic transmission consists in the employment of sound vibrations to operate upon electrodes, so as to vary the resistance at the electrodes, and thus control the current in conformity to the sound vibrations. His transmitter is more properly an automatic governor of the current, which is provided by a battery in the same circuit. His receiver consists of an electro-magnet, mounted upon a resonant case. Of these there are two varieties: One an electro-magnet without an armature, in which the varying current changes the magnetic strength, causing a corresponding molecular rearrangement, which produces the sound in air reinforced by the case; the other, an electro-magnet with an armature, provided with a spring to oppose the magnetic attraction on the one side, and a stop screw to prevent contact with the poles on the other side. The main source of the sounds in this is due to magnetic induction upon the armature, just as in the telephone of to-day. This, too, is mounted upon a resonant case. The instrument very closely resembles a common relay, the horizontal magnet, the hanging of the armature and the recoil spring are all there, and, as might be supposed, a relay makes a tolerable receiver.

Yates, of Dublin, placed a drop of water between the platinum electrodes in Reis's transmitter, and thus prevented the absolute break in the current to which Reis was liable; he also mounted the electro-magnet of the receiver in a better way, and so got

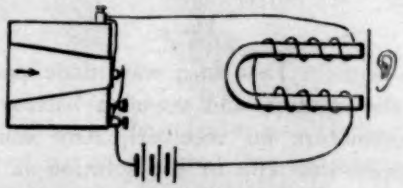


FIG. 3.

better results. Dr. Messel, of London, who was one of Reis's pupils, told me that Reis himself placed water and sulphuric acid and sulphate of copper solution, and various other solutions, in the same place and for the same purpose. This experiment of Yates, which is well enough authenticated for history and credence, teaches one lesson that has been overlooked so far in this telephonic controversy. It has been said over and over again, that if Reis had actually achieved the electric transmission of speech, that

everybody would have heard of it, that it could not have been buried and so little known of it, because the achievement was one of the highest importance, and therefore, if so little was known of Reis's speech transmission, it was because he didn't do it. But it is not denied that Yates did it in 1866, and that it was known at the time at the University there, but it did not appear to be of enough importance to even chronicle. Silence, therefore, does not tell against Reis, but against the contemporaries of Reis and Yates.

The grandest invention is of but little worth, except it be allied with business tact and energy. A steam engine is good for nothing without coal and stoking.

Elisha Gray, of Chicago, designed a speaking telephone and entered a caveat for it in the Patent Office early in 1876. The only difference between his plan and that which I have described, consists in the structure of the transmitter, which consisted of a metallic vessel, containing a liquid conductor, the top covered with a diaphragm, carrying at its middle a wire conductor, reaching

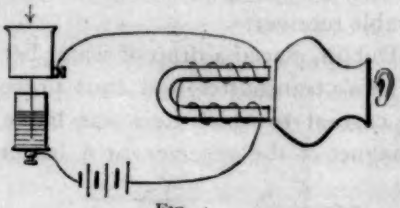


FIG. 4.

down into the liquid. This wire was made part of an electric current with the solution and vessel, a battery and an electro-magnet with armature for receiver. Any sound made at the diaphragm moved the wire in the solution in a corresponding way, and so varied the strength of the current by varying the resistance in the liquid. The receiver had the electro-magnet armature mounted upon a tube, which was advantageous for listening, as the sounds were thereby prevented from scattering to the degree they did with Reis's mounting. It did not differ in principle from Reis for the series of reactions from the sound to be transmitted, to the one that reached the ear were practically the same, namely, the air vibrations acting upon an electrode varied the resistance of an electric circuit maintained by a battery, and

the varying current varied the magnet's inductive strength upon the armature, causing it to move in accordance with such current changes.

McDonough, also of Chicago, about the same time had modified a Reis transmitter by making multiple platinum contacts, and lessening the liability to the disruption. His receiver was similar in structure to Gray's. This, considered as a system, is identical with Reis's.

Drawbaugh, of Pennsylvania, and Meucci, an Italian, both lay claim to the inventions of this system.

BELL'S SYSTEM.

Bell departed from the system already described. Beginning with the transmitter he dispensed with the movable electrodes and the variable resistance, and in the place of that apparatus he placed an electro-magnet with its armature, proposing to speak to the armature itself, which being set in, forced vibrations similar to the originating sound-waves, should react upon the poles of the magnet, and they upon the coils of wire surrounding them, and the current that was maintained in them by a galvanic battery, thus causing electrical waves in the circuit corresponding to the sound-waves

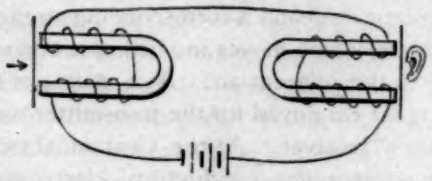


FIG. 5.

which produced them. The receiver was another electro-magnet similar to the first, but so mounted that the vibrations set up there should reach the ear advantageously. So far as the action at the receiver was concerned, it was similar in all respects to the action in Reis's receiver, nevertheless the whole is deserving the distinction of a separate system, for the receiver now became a transmitter, and thus it had an entirely new function in addition to the old one. *The really new thing about it was the transmitter*, which acted by setting up electro-motive forces in the circuit, which reacted upon the electro-motive force of the battery, and therefore varied the strength of current in the circuit. The successive steps

in this method are: Sound vibrations in air causing forced vibrations in the armature of the magnet, varying the strength of the magnetic field. The varying field reacts upon the coil of the electro-magnet, and the current of electricity present in it, setting electro-motive forces of a vibratory kind, now in this direction and now in that, according to whether the armature moved towards or away from the poles. The action is one of successive transformations of energy, the source of all the changing electro-motive forces being the energy of the sound vibrations themselves, and therefore quite unlike the Reis transmitter, which is simply a controller of the electric energy which is provided by a separate source.

In the Reis transmitter, the strength of the current is varied by mechanical means directly, while in Bell's transmitter the current is varied by magnetic means directly. The contrast is still stronger, for on the one hand the changing currents are really vibratory, to and fro in direction, while in the other the currents are all in one direction, only varying in strength. The one produces its effects by *changing the direction* of its currents, the other by *varying* the strength of a continuous current.

At the receiver, the succession of transformations is similar in each. The magnetic changes produced by the currents result in a varying magnetic field and a corresponding strength of attraction upon the armature, which moves in obedience and vibrates, imparting its energy to the adjacent air. As a matter of fact, the form of the electro-magnet employed for the transmitter was not the same as that used for a receiver. At the Centennial exhibition of the telephone, the receiver was a cylindrical electro-magnet, the coil being within the cylinder, the armature being a disc that fitted like a cover upon one end of it. This receiver was given to Sir William Thomson, who carried it home with him. During transportation, the armature got bent up to an angle of forty or fifty degrees from its proper position facing the poles. Sir William testified in a London Court, where he showed the receiver with the armature still bent out of place, that he had endeavored to make it talk after his return home, but had not succeeded, and he could not remember but that the armature was intended to be bent up as he found it on unpacking, so the man who made it was called up to testify what the intention was. I think that anyone less eminent than Sir William, who had been called as an expert, and who

should give such testimony as that, would be at once ruled out as incompetent.

In the same year, 1876, I proposed to employ permanent magnets for both receiver and transmitter, so as to dispense with a battery, and have each instrument of the same form. This was

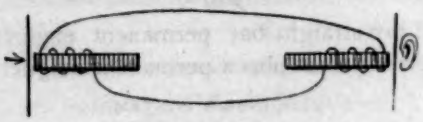


Fig. 6.

before I knew anything as to the instruments that Bell had employed, and the first one made was with a straight bar magnet with the coil wound over only one end. This kind was soon found to be much more efficient than the electro-magnet and battery, and was adopted to the exclusion of the other. Considered as a system, however, it differs from Bell's only in this, that in the latter, the generated currents modified the current permanently in the circuit, while in mine the generated currents were the only ones in the circuit. Several electricians have stated that the two are identical, and that the only object of employing a battery was to keep the magnets magnetized, in spite of the well-enough known fact that a magnet may be made stronger by permanent magnetism than by a current on a line of any considerable external resistance, without using an inordinate battery. Somehow I had, for twenty years, the idea of the reciprocal action of magneto-electric devices. I had tried, in 1855, to make one magneto machine run another one, and, failing to do it, wrote to the editor of the *Scientific American* to know why it didn't work. The response was one of two or three lines in the column to correspondents, which answer I have forgotten, for I haven't seen the number since that time. It was marked A. E. D., Mo, where I was living at the time. Also, in 1864, I proposed a similar plan for a telegraph, the sender and receiver to be alike, and with similar functions. I mention these in justice to myself and in order to point out that there was nothing that was new to me in such combination of actions.

The system used at present in *legal telephony* consists of a transmitter of the Reis pattern, and differing from it only in the substitution of hard carbon where Reis used platinum, while for a

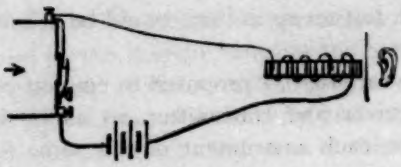


FIG. 7.

receiver is used my straight-bar permanent magnet telephone of 1876. It is Reis's system plus a permanent magnet.

BERLINER'S SYSTEM.

Berliner proposed a still more novel plan for a speaking telephone, because it involved principles unlike any of the others. His system consisted of a transmitter similar to the Reis's in prin-

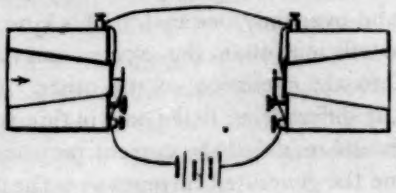


FIG. 8.

ciple, and his receiver was a duplicate of the transmitter. The two similar instruments were to be put in circuit with a suitable battery, when an electric current would traverse the line. Talking to the transmitter would vary the strength of the current, and this varying current would vary the temperature of the electrodes at the receiving instrument enough to develop there what may be called a modified Travellian effect, and produce a sound, the character of which would depend upon the varying rate of the electrical energy spent at the terminals. The receiver could then be used as a transmitter, so that, like the Bell system, each instrument had a double function. The Berliner receiver depended upon the convertability of electricity into heat, the latter at once doing work in moving the diaphragm. This was a highly ingenious plan, and is a system by itself, as much so as any I could name. The same principle has been varied somewhat and improved upon by others. I, myself, in 1878, used the heating effect of the current in a short wire to work a receiver.

Preece, in 1880 or 1881, likewise described some experiments of the same sort; while Cross has lately obtained surprisingly

good results by using a platinum wire about six inches long, fixed to the middle of the diaphragm, and a current strong enough to keep the wire red hot. He described the effect to be such that the talking could be heard several inches from the receiver. In my opinion, the transformations of energy are the same in these cases, and I therefore include them under the head of Berliner's system.

EDISON'S SYSTEM.

Ten or twelve years ago, Edison discovered that electricity was competent to lessen the friction between two surfaces, and, at first, adapted the discovery to a telegraphic receiver, and he gave the name Motograph to it. Later, he invented a telephonic transmitter, in which the current traversed a mass of lampblack, fastened between a solid back and a diaphragm, against which sound-waves could impinge. The vibrations of the diaphragm changed the conductivity of the parts and so varied the current. It is a variable resistance transmitter, in which lampblack takes the place of the platinum in Reis's transmitter. It was impossible, on account of the mechanical structure, that there could occur a break in the current in Edison's transmitter, and the changes in resistance were sufficiently great to make it excellent for its purpose. Edison then adapted his motograph to telephonic purposes, calling the modification a motophone, when he then pos-

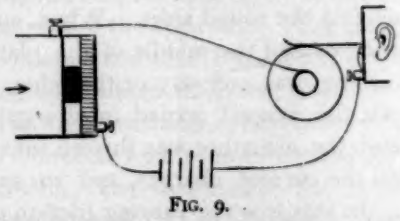


FIG. 9.

sessed a telephonic system which, for loudness of performance, leaves nothing to be desired. It embodied mechanical details in the transmitter that vastly increased its efficiency, and in the receiver there were transformations electrical, chemical and mechanical, such as had not been even known until his discovery. I am very strongly of the opinion that Edison's system is one quite distinct from any other, being radically different from anything found in Reis, or Gray, or Bell.

DOLBEAR'S SYSTEM, NO. 1.

In 1878, I devised what I called a battery transmitter, in which one of the battery plates was so mounted that the sound-waves could impinge upon it and cause it to vibrate. In fact, the plate was used for the double function of a battery element and an acoustic diaphragm, the other element of the battery, zinc, being thick and rigid. The cell was thin and small, holding but about a tablespoonful of dilute acid. When this cell was spoken to, the vibrations of the plate were sufficient to give the proper characteristics to the current which the cell itself provided, and speech was rendered in the ordinary receiver with distinctness nearly "sufficient

FIG. 10.

for every one." I also invented a new receiver combining the attraction of a magnet, and the varying friction produced by the varying magnetism. An electro-magnet made with a core which could be rotated on its axis within its coil had resting upon its two poles the two ends of a curved armature, the middle point to which was fastened to the middle of a diaphragm. When a current of electricity traversed the coil, the magnet attracted the armature, holding it snug against the round sides. When now the core was rotated, the adhesion caused the middle of the plate to be bent in or out, as the turning was one way or the other. If the current varied in strength, the magnet varied in strength, the adhesion varied with it, and the armature was thrown into vibrations that corresponded with the current charges, and so speech could be rendered with it. In this it is the varying friction caused by magnetic changes which is the cause of the sounds, not magnetic induction as in Reis, or chemical dissociation as in Edison's, while the transmitter had the double function of both battery and transmitter, and, therefore, in accordance with my method of distinctions, I rightfully call this a system.

DOLBEAR'S SYSTEM, NO. 2.

I once had a receiver so made as to permit a current of electricity to pass between two plates with a few drops of ammonium

chloride between them in the expectation that the decomposition effected by the current would result in gaseous products which would move the plates. I found the result I expected, and had a receiver still different in principle from any I have described, in as much as the dissociative chemical relations of the electricity was the immediate cause of the sound vibrations. At one time, while experimenting with this the liquid leaked from between the plates,

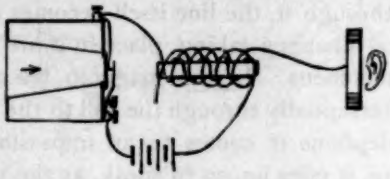


FIG. 11.

when I found I still heard the talking plainly. This new phenomenon I at once began to work out towards still better results until the receiver assumed its present form. For a transmitter, I found it necessary to use the high electro-motive force which I could only get from an induction coil. In as much as the receiver consisted of two plates as perfectly insulated from each other as it was possible to make them both by a thin layer of air and by thick varnishing, the resistance was practically infinite, and no current could traverse it; therefore a transmitter such as could only vary a current which must be maintained, was out of the question. An induction coil is an essential part of the apparatus. The complete transmitter consists of the variable resistant transmitter of the plan of Reis, hard carbon being used where Reis used platinum, combined with an induction coil of high resistance, 3,000 ohms or more, the terminals of this coil connected with the two plates of the receiver by the ordinary line wire. The structure of the receiver is such as to constitute it an air condenser, but in addition to that the varnishing upon the plates plays a very important part, an essential part in its commercial working, for it adds to the capacity of the condenser in two ways: (1.) As an ordinary dielectric, and (2.) in its absorptive property by which it becomes electrified, retaining its charge. It is then like a charged electroscope or electrometer, and is much more sensitive than when the plates are simply metallic and incapable of such electric action. In operation this system is radically different from the others, for (1.) it is not operated by a current.

The opposed plates are oppositely charged, and therefore attract each other. One of them is free to move slightly towards the other at its middle point, the strength of the attraction determining the amount of movement, but no current traverses the receiver for its resistance is measured by thousands of megohms and ohms law has no application to it. (2.) The electrical condition of the line is entirely different from that in the other lines, for as no electricity can flow through it, the line itself becomes a charged body, and any electrical changes taking place in it are of the nature of electro-static phenomena. In the magneto telephone the electricity goes uninterruptedly through the coil to the ground beyond. In the static telephone it comes to an impassible barrier and it accumulates there, it piles up, so to speak, as the tide does against the shore. The line, therefore, may have its electrical condition likened to an ocean tide and a continuous change of level, while the magneto line may be likened to an unobstructed river with variable quantities of water flowing. Prof. Cross who has made measurements of the current strength employed in telephones with various transmitters, reports that there was no measurable current in my line, which is just what I have maintained from the outset must be the case. But there have been some electricians who have declared that so far as the line was concerned there were currents in it just the same as in the common telephone lines. (3.) High electro-motive force is another essential condition. A battery and a transmitter, however good for magneto purposes, will not work my receiver, for it is the function of the transmitter to vary the current, and if there be no current evidently there can be nothing to vary.

As both transmitter and receiver are necessarily unlike any of the others, and as the transferring line is in a different electrical condition, and the character of the transformations of energy not to be found in the others, it is a system by itself.

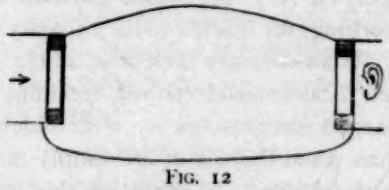


FIG. 12

If two receivers be placed in same circuit uncharged, if one

attempts to use the arrangement for the transmission of speech he will fail, for merely vibrating one plate near another will not generate an electrical phenomenon, but if the line be charged in any way, one may then use each instrument as transmitter or receiver. In this way I have worked successfully over a half mile of line with the most ordinary insulation.

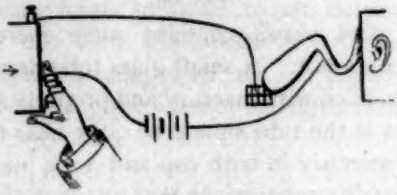


FIG. 13.

(4.) In 1878 I found that if an electric circuit was completed through the finger in contact with the bottom of a tin cup, the current on the line would be varied by the change in pressure produced by sound vibrations in the cup, so that it was a variable resistance transmittter. With a dozen gravity cells and the end of the finger moistened it is a tolerably efficient transmitter. The receiver with which I have represented this transmitter in circuit is an ideal receiver which I have threatened to make every summer for six or eight years, but have never done it. Ever since Galvani's experiment with the frog's leg that has been a standard experiment, yet I confess I never witnessed the phenomenon. It is said that the properly prepared leg of a frog is a particularly delicate electroscope, and that it only requires the contact of a piece of zinc and copper to throw the leg into spasms. I therefore proposed to connect such a leg with the plate of a telephone, completing the circuit through the leg, a battery and a transmitter, expecting that the changing currents would cause corresponding muscular movements of the frog's leg which would be communicated to the plate, in which case the diagram represents still another system.

BREGUET SYSTEM.

There is but one other complete system that I chance to know of, and that is Breguet's. Lippmann made the discovery that the surface of mercury was visibly deformed by a current of electricity upon it from the point, and Breguet reduced this to telephonic purposes. Transmitter and receiver are both alike and have similar

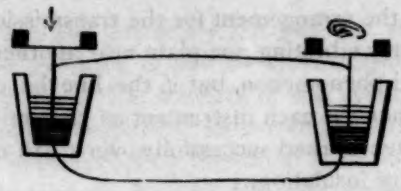


FIG. 14.

functions. A glass vessel contains some mercury with some acidulated water upon it. A small glass tube drawn to a point but not closed, is also filled with mercury and properly supported above, so that the point of the tube should be quite near the surface of the mercury. The mercury in both cup and tube must be provided with external metallic connections that an electric circuit may be completed. When these two are connected thus, any motion of either tube towards or away from the surface will be followed by a corresponding motion of the other.

There are several telephone inventions of importance, and some of them of the highest, that are in the nature of improvements. Transmitters and receivers have both been made more efficient by their use, while some have only a scientific and theoretical interest. A few of these I shall notice.

Among transmitters embodying difference in principle I would name the thermo-electric-pile. In 1873 I described at the Portland meeting of the American Association for the Advancement of Science, an experiment I had made "On the Convertability of Sound into Electricity," in which the vibration of a tuning fork upon the face of a thermo-pile had developed electricity. At the time the criticism on the paper was that the vibration resulted in heat, which was the cause of the phenomenon.

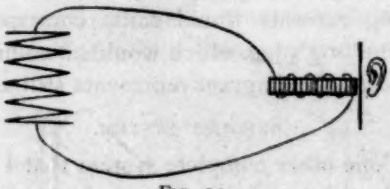


FIG. 15.

As soon as the magneto telephone was available for the test I coupled it in circuit with a thermo-pile and applied the tuning fork as before, and at once heard the pitch of the fork at the

receiver, and that, too, at the distance of half a mile from the thermo-pile. I have also heard the voice, but only very weakly, with a thermo transmitter. The electro-motive forces are at best but about ·0001 of a volt, and with such nothing much can be expected. As contrasted with such weak currents an electric arc, half an inch long, is at the other extreme.

As the arc is exceedingly sensitive to air currents, and as an arc may be blown out with the breath, it occurred to me that possibly the changes in density in air vibrations made to go through an arc would vary the current strength enough to enable

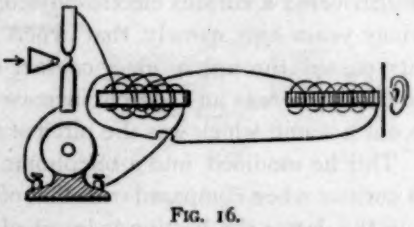


FIG. 16.

sounds to be reproduced by it. The sounds were directed to the arc by a speaking tube, every word spoken driving the sparks two or three inches away from the arc. The current was passed through the primary wire of a large induction coil that could not be injured by such a current of fifteen or twenty ampères. The terminals of the secondary connected alternately with the magneto and the static receivers. Only the faintest show of a sound could be heard. I did, however, hear some sounds, but not speech. Whistling was plainest.

I discovered one thing of interest and of some importance, too, as bearing upon future improvements in transmitters; that is, that the most sudden break of such a current produced an hundred times less sonorous effect in the receiving telephone than the break from a single Leclanché cell would give. The explanation probable is that it is impossible to produce a sudden enough break to effect the telephone, so that the ear could perceive it. Not that the ordinary effect of magnetization and demagnetization are not perceived, but their gradualness prevents an acoustic effect. It was not possible to get a spark of any appreciable length by the breaking of such a current, though with half a dozen bichromate cells a spark four or five inches long was easily obtained. As it has been

found by experience that an electro-motive force greater than three or four volts in the primary circuit with a Blake or other transmitter of that kind was not so efficient as less. I take it to be explained that within the slight movable distances, to which the terminals of such transmitters are subject, the formation of an arc across the space is detrimental to the performance, for if there be an arc the current is not varied, it continues right on with no considerable diminution. It is, therefore, necessary to use a lower electro-motive force, and that from two Leclanché cells, say three volts, is as much as can ever be employed with such transmitters.

Elisha Gray discovered a curious electro-physiological phenomenon a good many years ago, namely, that when vibratory high tension currents passed through a finger contact upon a movable metallic surface that there was an apparent increased adhesion, and the metal gave out a sound which was the pitch of the interruption of the circuit. This he modified into a telephonic receiver. The phenomenon is curious when compared with that of the motophone of Edison, for in the latter the friction is lessened by the current, while in the former it is increased.

Lastly, there are three telephonic receivers, which have nothing but novelty to recommend them, but I thought you might like to know of them.

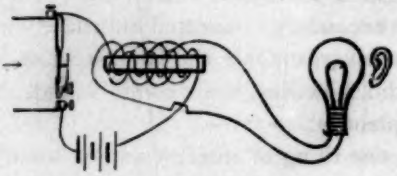


FIG. 17.

(1.) An incandescent electric lamp of the ordinary sort makes a speech receiver. The current needs to be a strong one, and it performs better when the current is sufficient to heat the filament to low redness. I suppose it is to be explained by what I have described under the head of Berliner's system.

(2) Crooke's tubes may be similarly employed, only a high resistance induction coil is needed. By using one in which the gaseous impacts are against the side of the tube, or bulb, and that held against the ear, one may hear the spoken words.

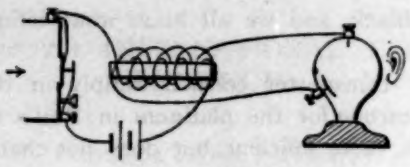


FIG. 18.

(3.) A Leyden jar of the ordinary pattern held, one hand grasping the outer coating while the knob is placed in the ear, the two coatings being the terminals of a secondary from almost any kind of a transmitter.

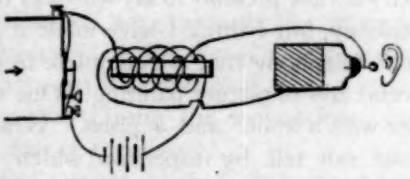


FIG. 19.

It was Hughes, of England, who discovered the great sensitivity of hard carbon and pointed out its adaptability to telephonic purposes. A discovery of such importance, that if he had seen fit to patent, as he might have done, he would have practically controlled the telephone for commercial purposes. The Royal Society of Great Britain has just honored him for this among other distinctions. It has been claimed by those who own the right to the use of plumbago and lampblack for such uses that they also own hard carbon of any sort, but they are no more to be compared than peet and anthracite.

The properties of a body are not the properties of the atoms of the body, but depend upon the molecular constitution and arrangement of the body. It is the atom that is named carbon. It is the molecular properties that are wanted, and the molecular properties are not the same in lampblack and gas coke. If one should discover that starch could be used for a certain useful purpose, and afterwards some one should discover that cotton would answer very much better, and if the first should then claim the cotton because he first described an amylose for the purpose, the cases would be similar. Yet I heard Sir William Thomson say that it required but an infinitesimal amount of invention to substitute gas

coke for lampblack, and we all know what infinitesimal means to him.

The Blake transmitter consists simply in the adoption of Hughes' hard carbon for the platinum in Reis's transmitter. It makes it much more efficient, but does not change its mode of operation nor vary the mechanical relations.

Hunning, an English clergyman, has made a very useful transmitter by employing granulated hard carbon, arranged mechanically in the circuit as Edison arranged his carbon button, and with this transmitter the best long line work has been done.

In conclusion, I do not pretend to say who was the first inventor of an art of telephony, but I think I have made it plain that there are several arts of telephony that are complete in themselves, just as there are several arts of picture painting. One man paints with a brush, another with a roller and a press. When the pictures are done, no one can tell, by inspection, which way either was made, hence it is improper to speak of *the* art of picture making. Leaving out all that was done before 1876, I submit that the work of that year ought not to control systems that have been invented and discovered in their entirety since that time, and have almost nothing in common with it. I protest against it in the name of law which has been misjudged; I protest against it in the name of equity which has been scandalized; and I protest against it in the name of science, whose eyes are not bandaged as are the eyes of justice, herself a judge, the court of highest appeal, and who writes after every signature to a judgment in her court, *competent* or *incompetent.*

GENESIS OF CHOLERA.—In a recent sitting of the French Academy of Medicine, Professor Peter expressed the opinion that European and Indian cholera differ only by the relative morbific intensity of the producing causes. The two forms may arise spontaneously, either in Europe or in India, being engendered in either case by volatile ptomaines produced by organic putrefaction. M. Gustave Le Bon reports some interesting observations, made during his visits to India, which strikingly corroborate these views. The cholera in India is confined almost exclusively to the Hindoo population. Even in the great cities all the English live in cantonments, which are reserved for their exclusive use, at some kilometres from the towns. The hygienic arrangements are very complete; neatness is pushed to excess, and the most scrupulous attention is paid to the origin of the water which is used. —*Comptes Rendus, Sept. 21, 1885.*

GLIMPSES OF THE INTERNATIONAL ELECTRICAL EXHIBITION.

By Professor Edwin J. Houston.

[*Concluded from Volume CXX, page 388.*]

NO. 8. REIS'S INVENTION OF THE ARTICULATING TELEPHONE.

In telephonic communications, mechanical vibrations of the transmitting diaphragm, are, through the agency of electricity, mechanically reproduced at the receiving diaphragm. The question in dispute between Reis and Bell, is, as to the nature of the electrical currents that transfer the motion from the receiving to the transmitting end of the circuit.

Can an electrical current in which makes and breaks occur successfully transmit articulate speech? This question it will be perceived is vital to the interests of Bell, since, unless he can maintain the absolute necessity for his undulatory current, the extent of his alleged invention is very considerably decreased. Instead of having created a new genus of apparatus, he has merely produced a modification of what has already existed. Apart, therefore, from the question of what Reis really intended by his makes and breaks let us carefully examine this question.

Scientific men have by no means given unqualified assent to the necessity for the employment of an undulatory current in the telephonic transmission of articulate speech. On the contrary many of the ablest physicists and electricians have expressed grave doubts in the matter. I will give a few quotations to this effect, taken from testimony in some of the Bell Telephone suits for alleged infringement. Dr. Wm. F. Channing testified in one of these suits as follows; viz.,

Q. "And don't you also know or believe that the electric transmission of speech depends on the precise mode of operation stated in that question?"

A. "I do not. It is the merest assumption that no other method exists for the transmission of articulate sounds than what is called the undulatory current. The vibrations of sound which enter

into articulation are not undulatory (in the form usually represented by graphic curves) In their ultimate analysis they are to-and-fro vibrations in a straight line.

They do not resemble the waves of the ocean nor the undulatory curves which for convenience are made to represent the form of simple or compound sounds in their relations to time. We have no evidence whatsoever that any articulate sound cannot be reproduced in the telephone by as many separate electrical impulses as there are separate sound vibrations, the electrical impulses corresponding precisely in number, intensity and combination with those of sound."

Again, speaking of certain tracings, or records, obtained by means of a machine devised by Prof. E. W. Blake, for describing Compound Harmonic Curves, he says,

"The characteristic to which I wish to draw attention in all these records, is that the effect of compound sounds, such as enter into articulation, is to produce a very few abrupt and marked changes in the motion of the telephone diaphragm, and of its equivalent in the phonograph. I wish also to draw attention to the fact that these changes in the motion of the diaphragm, which are the principal characteristics of its articulatory action, are often or mainly arrests or reversals of its motion. An arrest of the motion of the diaphragm means an arrest of the current. A reversal of the motion of the diaphragm, means an interruption and reversal of the electric current."

"Interpreting thus these graphic records, I have no hesitation in saying that the elements of articulation which are actually influential on the plate, and which ever actually reach the distant receiving end of the line, may consist entirely of makes and breaks of different order, duration, and force."

Again in the same answer

"I do not believe that the electric undulations are ever similar in form in any accurate sense to the vibrations of the air accompanying the sounds of the voice made in a transmitter. The method of electric transmission is complex and artificial, and for reasons already stated differs widely from the air vibrations which originate it."

Prof. Cyrus F. Brackett testifies in one of the above suits as follows:

Q. "Do you know it to be true that a simple sound represented by a sinusoidal curve cannot produce an electrical undulation by the intervention of an inductive action which can be represented graphically without error by the same sinusoidal curve; and if you know that to be true when and how did you make that discovery?"

A. "I am as sure as I am of most facts on which we place implicit confidence that while such undulations may be graphically represented with approximate similarity, they cannot so be represented without error; and as I have been asked when I made that discovery, I may answer generally that the results in telephonic transmission, as a matter of fact, never do, to the best of my knowledge and belief, exactly correspond with and copy the sounds delivered to the transmitter. Accurate date as to when I made this discovery I cannot give. It is notoriouly a subject of discussion by mathematicians and experimental physicists to determine the laws which govern the changes found to exist between the spoken and received words of a telephone. My knowledge is partly derived from experience and is partly theoretical."

Again the same witness,

Q. "Assume it to be true that the circuit is broken and closed at each vibration, is it your opinion that such an apparatus as that combined with the best receiver now in use, and without any other apparatus, except the battery and wires, can transmit articulate speech practically."

A. "I have no question whatever that it is entirely possible on the hypothesis in the question to so transmit articulate speech, and I will give my reasons in part: When a circuit is closed, as that term is commonly used, it by no means follows and is not true that the current suddenly reaches its maximum, and it is not true that when the circuit is interrupted, as assumed in the question, that the current suddenly and immediately ceases along the whole line. Several conditions will determine its establishment and cessation, among which may be mentioned the length and resistance of the line, its static induction, its mutual induction arising from the necessary introduction of magnet in the circuit, etc. It, therefore, follows that if the making and breaking, assumed in the question, are properly timed relatively to each other that the effect at a distant point at which a telephonic receiver may be placed will be such that it will be thrown into vibration under the impulses of

the electric pulses or undulations which reach it and which may be made to be of the proper form to reproduce the words spoken in the said assumed interrupting transmitter."

Again in answer to another interrogation the same witness testifies

"It is still (Mar. 15, 1884) an open question, whether that class of instruments known, popularly as circuit breakers, of which Reis, McDonough, Hughes' microphone, Blake transmitter, etc., are examples, operate by making and breaking the circuit, so as actually for minute intervals of time to thereby reduce the current to a minimum, or whether they act through continuous contact by varying pressure to alter the resistance in the line in substantial accordance with the vibrations constituting sound as employed in articulate speech."

So also Prof. C. A. Young, deposes as follows:

Q. "Did you mean to say that in your opinion the microphone operates by making and breaking the circuit, and not by varying the strength of current which is maintained through the joint during the operation of transmission?

A. "I intended to say that in my opinion it is not yet (Feb. 13th, 1884) certain in what precise manner the microphone produces variations in the strength of the current at the receiving end, and that in my opinion the theory that it is done by minute makes and breaks is not demonstrated to be false."

Again. *Q.* "In your opinion, does the intelligible transmission of speech require that the motions of the receiver-membrane or diaphragm should be a strict copy of the motions of the air in contact with the transmitter, and if not, why not?

A. "It does not. Undoubtedly speech can be transmitted by such a strict copying—but such a copying is by no means necessary. The characteristics of a spoken word which render it intelligible as such, do not consist either in the absolute pitch of the sounds made, nor even in the quality of the sound, as that term is commonly understood. A fact, which is evident from this, that a given word spoken by a woman and by a man will differ in both these respects."

These opinions could be readily multiplied but those given above will suffice for the present.

With the above and similar opinions Mr. Bell is at variance.

Simple sounds, in his opinion, may be transmitted by means of complete makes and breaks in the electrical currents, but complex sounds, even such as simple chords, cannot be readily so transmitted. Let us examine carefully the argument as given in his U. S. letters patent and elsewhere, by which he endeavors to prove this assertion. He is discussing, in his patent of Mar. 7, 1876, the attempt to simultaneously transmit, by what he terms intermittent currents, two sounds the interval between which is that of a major third, or 4 to 5; he speaks as follows; viz., "Now, when the intermittent current is used, the circuit is made and broken four times, by one transmitting instrument, in the same time that five makes and breaks are caused by the other. *A*, and *B*, *Figs. 1*, *2*, and *3*, (*our Fig. 17*)

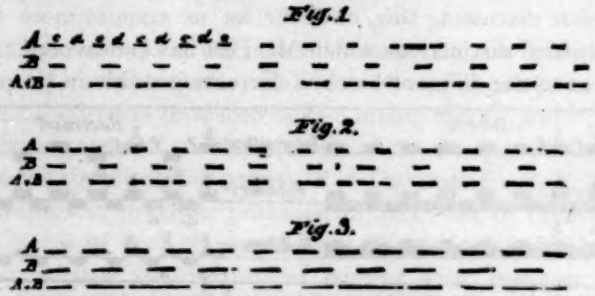


FIG. 17. Bell's ideal representation of effects produced by the simultaneous transmission of pulsatory currents of different rates.

represent the intermittent currents, produced; four impulses of *B*, being made in the same time as five impulses of *A*; *c*, *c*, *c*, etc., show where and for how long the circuit is made, and *d*, *d*, *d*, etc., indicate the duration of the breaks of the circuit. The line *A* and *B*, shows the total effect upon the current when the transmitting instruments for *A*, and *B*, are caused simultaneously to make and break the same circuit. The resultant effect depends very much upon the duration of the make relatively to the break. In *Fig. 1*, the ratio is as 1 to 4, in *Fig. 2*, as 1 to 2; and in *Fig. 3*, the makes and breaks are of equal duration. *The combined effect, A, and B, Fig. 3, is very nearly equivalent to a continuous current.* (*Our italics.*)

"When many transmitting instruments of different rates of vibration are simultaneously making and breaking the same circuit, the current upon the main lines becomes for all practical purposes continuous."

The idea intended to be conveyed is that when an endeavor is made to simultaneously transmit several rates of vibration by intermittent currents, the intervals that exist between the successive makes of any one of the tones, during which it is assumed that no current passes, will be occupied by some or all of the intervals that exist between the breaks of the other tones, so that a continuous current will result in which the characteristics of its separate components cannot be detected.

Would this be the case? We think it can be shown that Mr. Bell has thus introduced into his specification graver errors than those imputed to Mr. Reis in the interpretation often put on his description of makes and breaks.

Before discussing this, however, let us enquire more fully into the artificial distinctions which Mr. Bell has endeavored to sharply draw as to the different kinds of currents possible in telephony.

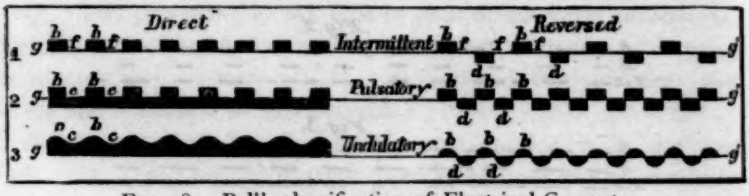


FIG. 18. Bell's classification of Electrical Currents.

Fig. 18, is taken from a chart used by Bell in a lecture delivered before the Society of Telegraph Engineers, in London, Eng., on Oct. 31, 1877. This chart recognizes three primary varieties of telephonic currents, viz., the intermittent, the pulsatory and the undulatory.

The intermittent current is one which is alternately present and absent from the line.

The pulsatory current is one which "results from sudden or instantaneous changes in the intensity of a continuous current."

The undulatory current, is "one in which the intensity varies in a manner proportional to the velocity of the motion of a particle of air during the production of a sound."

Of each of these primary currents there are two varieties, viz., the direct and the reversed.

In speaking in a public lecture, of the effects produced by the simultaneous transmission of several notes of different pitch by means of intermittent currents, he calls attention to the diagram

shown in *Fig. 19*, which with *Fig. 18*, is taken from Prescott's work on the Speaking Telephone.

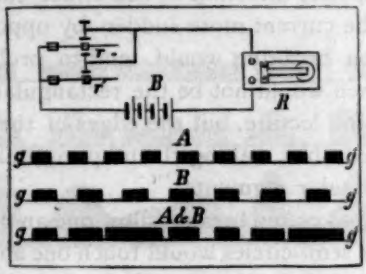


FIG. 19. Simultaneous Transmission of Several Intermittent Electrical Currents.

In this figure as before, the interval between the two tones is that of a note and its major third. The lines *A*, and *B*, are intended to represent the currents produced by two tuning forks *r*, and *r'*, tuned to the above interval, and vibrated so as to simultaneously open and close the circuit of the battery *B*. The line *A* and *B*, is supposed to represent the effect produced on the circuit by the simultaneous presence of both the notes, and is intended to show that the result is still an intermittent current with, however, some of the intervals extinguished.

In the case represented in this figure the intervals in which there is supposed to be no current are assumed to be equal to those in which the current exists. Both in the patent already referred to, and in his lecture, Mr. Bell has represented a state of things that it is difficult to conceive of as ever actually existing in practice. Certainly he can not realize it by the use of the means he describes. We refer to his representation of the current as suddenly beginning and as suddenly ceasing to flow. With the arrangement of parts as shown in *Fig. 19*, and indeed with the actual condition of all telephonic circuits, such a condition could never be attained in practice. In even comparatively short lines, some time would be required to charge the line and thus establish the current, and some time would undoubtedly be required to discharge the line, and thus cause the current to cease, while in large lines the intervals of charge and discharge would necessarily be prolonged. So too, the effect produced by the induction of the current on itself, both on making and closing the circuit, would beyond question make the representations

of the abrupt beginnings and endings of the currents pictured by Mr. Bell, as false and misleading. The inverse current on closing, being in the opposite direction to the direct current, might make the starting of the current more sudden by opposing it, while the direct current on breaking would tend to prolong it. The true representative then would not be the rectangular spaces as figured in Bell's patent and lecture, but the edges of the rectangles should be cut off rounded, thus making them approximate more closely to half circles, or circular segments.

Now let the makes and breaks follow one another more rapidly; then the adjacent semi-circles would touch one another and the line would never be quite free from an effective current. It would, however, be subject to variations in strength, which Mr. Bell conceives may take place suddenly or instantaneously, thus producing the pulsatory current, or rather, as we have shown, necessarily taking place gradually, and thus producing the undulatory current.

The distinctions therefore drawn by Mr. Bell between the intermittent, pulsatory, and undulatory currents appear in actual practice to be rather differences of degree than of kind, and the assertions so frequently made that mere makes and breaks cannot possibly produce undulatory currents in a line, are apparently groundless.

But Mr. Bell asserts that the necessary effect of simultaneously throwing on the line a number of variously timed intermittent currents is to produce a uniform or practically constant current, in which the peculiarities of its separate components are necessarily lost. Let us enquire carefully into the truth of his assertions, since if he is correct then the statement we have made in the preceding paragraph is inaccurate

Mr Bell's manifest error in this regard has been ably pointed out by Locht-Labye, in a recent number of *La Lumière Electrique*, who suggests, referring to Mr. Bell's lecture, that if a single battery be employed for each interrupter of the current then the statement of the uniformity of the resulting current is entirely erroneous and based on a failure to properly consider the conditions of the problem. For, it is evident, that taking the case of a note and its major third as represented in *Fig. 19*, if each interrupter had its separate battery, there would necessarily be times during which the interrupters would be jointly throwing their currents into the line, thus producing a current whose intensity would at such moments

be the sum of the two: there could not then possibly result the hypothetical uniform current so positively stated by Bell as necessarily ensuing.

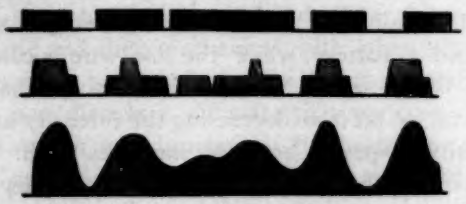


FIG. 20. Effect of Simultaneous Transmission of a Note and its Major Third.

In *Fig. 20*, which is collated from the *Scientific American Supplement* for May 23, 1885, the upper drawing shows the effect which Bell asserts would be produced on a telegraphic line from the simultaneous transmission of a note and its major third by the use of an intermittent current. The lower line, Bell's representation of the effect produced by the simultaneous transmission of the same notes by means of undulatory currents, while the middle line represents the effect which would probably be produced by the simultaneous transmission of these notes by intermittent currents when each interrupter was furnished with a single battery. The evident similarity of the second line with the third will be apparent.

If currents represented by the middle line in the above figure can be produced by the simultaneous transmission of but two different rates of intermittent currents, what must be there sult when more than two are thus transmitted? Must not the result be the practical production of the undulatory current?

Examining again, therefore, in this light, Bell's classification of currents as shown in *Fig. 17*, is it not evident that the direct intermittent current must become in some cases truly undulatory, and that the direct pulsatory current cannot fail in actual practice to be invariably undulatory? And if this be true of the direct currents, must it not be still more apparent in the case of the reversed currents?

We repeat, therefore, that the differences pointed out by Mr. Bell between the intermittent, pulsatory, and undulatory currents, are in practice rather those of degree than of kind. We therefore conclude that it is not impossible to transmit articulate speech

through the proper succession of discontinuous currents of sufficiently short duration.

It has been pointed out in some of our previous articles that in the great majority of cases in actual practice the telephone circuit employs the induction coil, the transmitter being in the circuit of the primary and a battery, while the line wire is connected with the secondary of the coil. Now it is well known that the use of an induction coil, so far from decreasing the intensity and clearness of the transmitted speech, actually increases both. This could hardly be the case if the currents sent into the primary wire by the transmitter had the gradual variations in intensity, that the undulatory current would seem to necessitate. They must, therefore, have sudden variations.

Commenting on Bell's assertion that for any sound to be transmitted telephonically "electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds," must be thrown into the line, Locht-Labye in the article before alluded to very neatly says:

"If Prof. Bell's theoretic ideas were admissible in a general way, and if an application were made of them in the other departments of physics, it would be necessary to adopt this formula: A physical phenomenon, during its diffusion through several media, and by different agents, must preserve all its peculiar characters without alteration in duration or form This is an absolute negative of the law of the transformation and *reversibility* of phenomena recognized in a general way in physics. Can this formula, which, applied to the different departments of physics and chemistry, would constitute a scientific heresy, be the expression of truth in telephony? Such derogation with so general a rule would at least be surprising!"

In conclusion he speaks as follows:

"The abrogation of the law recognized in physics does not, as Prof. Bell has supposed, exist."

"Telephonic transmission by electricity obeys the general law of the reversibility of the phenomena of nature, which, after a series of successive transformations, in which their peculiar characters and phases may be absolutely modified, reappear with all their constituent qualities."

"The original sound is produced by mechanical action. In its

propagation through the air, and then through the solid parts of the telephone, the mechanical motions are effected with the qualities proper to each of these media. Mechanical motion is afterward partially converted into magnetic or electric motion of several natures, though one or several inductions, in order to become again magnetic and then mechanical, with phases in the receiving telephone contrary to those it had in the transmitter.

We will now discuss a difficulty that perhaps with some has stood in the way of an admission of the possibility of mere intermittent or pulsatory electrical currents transmitting articulate speech. We refer to the fact that speech can be transmitted with the use of the magneto-electric telephone. Now it is probably argued that by the use of the magnetic inductions produced by the movements of the diaphragm by the sound waves that undulatory currents are thereby set up in the coils surrounding the magnets: or, as Bell would say, "an undulatory current of electricity" "the undulations of which correspond, in rapidity of succession to the vibrations of the magnet, in polarity to the direction of its motion, and in intensity to the amplitude of its vibration." It must not be forgotten, however, that though such currents may theoretically be produced, in reality, owing to the time required to charge a long line, and the impossibility of instantaneously or suddenly changing the direction of a current already established, as well as to the retarding effects of induction of the current on itself, or on neighboring wires, or of neighboring wires on the current, it may be regarded as scarcely probable that true undulatory currents in the sense described by Bell are transmitted over the line even in such cases. It is because these currents have generally been regarded as undulatory, and are known to transmit speech, that some have doubted the ability of any others to transmit speech.

Admitting, for sake of argument, the true undulatory character of the magneto-electric telephone currents, the objection against the possibility of intermittent or pulsatory currents transmitting speech is based, it appears to us, as a misconception of what actually occurs in the undulatory field in close proximity to a speaker, and in the undulatory field near the ear of an even moderately distant hearer. It has been assumed that all the peculiarities of the field at the transmitting end, must necessarily be reproduced at

the receiving end in order that intelligible articulate speech may be transmitted. Now such is not even generally the case. The finer vibrations or overtones, that constitute what is recognized as the quality of a speaker's voice, may be gradually dropped out of the sound waves without at all interfering with the intelligible reception of the speech. Indeed, were this not true it would be impossible for two persons to converse at even inconsiderable distances apart, since, as is well known, the amplitude and the energy of the overtones of all compound sounds are exceedingly small so that the overtones fade off very rapidly from the point of origin of the original sound. Mayer has shown that the finer overtones are so rapidly extinguished that at no very considerable distance from the speaker they become too weak to be heard. The author, too, has found that in the transmission of the human voice through rods of deal, the overtones were practically extinguished at even short distances. Such extinctions do not, however, prevent the intelligible transmission of speech. Speakers can be understood even when at such considerable distances that none but the stronger vibrations are transmitted.

Articulate speech may therefore be rendered by air waves that omit some of the original components. The undulatory motions at the hearer's ear are not only not necessarily, but not even generally exact copies of those at the speaker's mouth. There is no physical reason therefore why articulate speech may not be transmitted electrically by means of suitably timed makes and breaks.

A similar analogy exists in case of the eye. The brain takes correct cognizance of a printed page, though never read before, even if an opaque body like a sheet of paper be so held as to obscure all of a single line except about one-fourth or one-fifth of the letters. Habit permits us to mentally supply the portions effaced. So too with the ear. We can supply intelligently the portions needed, and this not only in the case of detached words, or portions of conversation, but in extended discourse.

It is not impracticable, therefore, in view of these facts, and of the conditions of the establishment and discontinuance of currents in long lines of conductors, that speech may be successfully transmitted by means of intermittent currents, even when comparatively extended breaks occur in the same.

That speech actually has been transmitted by means of strictly

intermittent currents, we will deduce a few of the many experiments tried by different investigators.

The London *Electrical Review* describes an experiment in which there was interposed in the circuit of a microphone transmitter, a ribbon of paper similar to that employed in automatic telegraphy. The paper had small holes very near each other, extending longitudinally through its middle. The paper, which was placed beneath a wire brush and over a metallic drum, and moved at the rate of 1,000 words per minute. There were thus, beyond any possibility of doubt, makes and breaks introduced into the telephone circuit at the rate of several thousand per minute. When now under these circumstances, that is while the paper was in rapid motion, speech was uttered at the microphone, it was intelligently received at the receiving telephone. Speech can therefore be transmitted though makes and breaks are continually occurring in the circuit.

But can speech be transmitted by means of the currents which are thus actually made and broken? I will quote here the description given by Dr. Wm. F. Channing, of an experiment made by McDonough.

"I am able to adduce, what I will not call a proof, but an evidence, much more direct than this, that articulation may be produced by the method of an electric current actually made and broken. An instrument has been constructed and is in existence, in which what I think must be accepted as undoubted, articulation is produced by simply making and breaking the electric current. This instrument consists of a toothed-wheel rheotome of about thirty-seven inches diameter. The wheel is of iron with a brass tire. This tire has a large number of minute serrations, on which in rotation, a spring bears. The spring is connected with a single Leclanché cell, the other pole of which passes to a large electromagnetic telephone receiver, the return wire of which is connected with the axis of the rheotome wheel. The serrations on the tire of the wheel, I understand, were planned, as regards their distance and grouping upon a careful study of a phonograph record. When this wheel was turned by hand, I heard the word "hello" proceed from the tambourine receiver. The sound of the aspirate *h*, and the *e*, and the *o*, were very good. The articulation, as good as I have often heard it in telephones, was due simply to makes and breaks of the electric current, so arranged as to effect changes in the pitch and the intensity of the sound produced in the receiver."

Other experiments have been made in this direction, but the above will suffice.

We have already pointed out that the undulatory movements of the diaphragm of the receiving telephone, though not exact copies of the undulatory movements at the transmitting diaphragm, are nevertheless undulatory in their character. Let us now briefly enquire whether properly timed makes and breaks sent over the line are capable, on theoretical grounds of producing such movements in the receiving diaphragm.

It appears to be tacitly admitted by the advocates of Bell, that although in transmitting instruments of the microphone type, partial makes and breaks may take place in the electrical contacts, yet, if the circuit is not completely broken that such a current may transmit intelligible speech, since the variations thus thrown on the continuous current passing in the line produces therein a true undulatory character. Now apart from the fact that it is by no means clear to us that such a current is not pulsatory rather than undulatory, still, since we have already pointed out, the difference between pulsatory and undulatory currents is one of degree rather than of kind, we may for sake of argument admit its undulatory character, and agree that it is so because the current is never entirely absent from the line. But according to the same argument, if a sufficiently great number of separate electrical sources were throwing their current on a continuous current they would thereby render it undulatory.

Fixing our attention now on what occurs when any current reaches the magnetizing coil surrounding the magnet at the receiving instrument, we will at once perceive that if this is a permanent magnet, as used by Reis in some of his instruments, *that the permanent magnetism of the receiving instrument plays exactly the same part as the continuous current is obliged to play in the microphone transmitter.* The varying currents passing over the line either increase or decrease the strength of such permanent magnetism and set up therein true undulatory effects. If these makes and breaks can produce undulatory effects in a continuous current, *then makes and breaks, pure and simple, passed over a telegraph line, must necessarily be able, when changed into magnetism, to similarly produce undulatory* effects in the magnetic field of the receiving instrument.

We would infer, therefore, that it should on theoretical grounds be possible to convert undulatory effects at the transmitting telephone into properly timed intermittent currents, *i. e.*, makes and breaks; to transmit them over a line and produce at the other end in the receiving diaphragm, undulatory effects that are sufficiently exact copies to correctly reproduce the speech uttered into the receiver. It is by no means clear therefore that Reis did not more accurately describe the operation of his telephone than Bell claims to have done.

In concluding the brief history we have given of Reis's invention of the articulating telephone, we have thought it advisable, as far as possible, to append the views of some of the leading scientific men in the United States concerning the position, which in their opinion, Reis occupied as regards the invention of the articulating telephone. The list is by no means exhaustive; nor has any attempt been made to obtain the opinions of those known to be adverse to Reis. It fairly shows the error of the statement that the leading scientific men of America, recognize and fully endorse the pretensions of Bell.

The following circular letter was sent, viz:

HALL OF THE FRANKLIN INSTITUTE, PHILADELPHIA, 1885.

My Dear Professor:—I purpose concluding my articles on the Reis Telephone, with a publication of the opinions, as far as I can obtain them, of some of the scientific men in the United States, as to the part taken by Reis in the invention of the articulating telephone.

Will you therefore write me at your earliest convenience, your opinion as regards the following interrogatories, viz:—

First. Please say whether or not in your opinion Reis was the inventor of the speaking telephone?

Second. Whether, if it was a speaking telephone, it worked substantially in the same way as the Bell Telephone, or not?

Third. Whether the electrical current employed in the transmission of speech was an undulatory current in the same sense as it is in the Bell Telephone, or not?

Fourth. Whether Reis ever actually succeeded in transmitting articulate speech as he claimed?

Fifth. Whether the defects in the Reis apparatus are to be attributed to his transmitters, or to a want of sensitiveness in his receivers?

Sixth. Whether the modern transmitting telephones of the variable contact type are anything more than the Reis transmitters with carbon substituted for the platinum contacts?

Thanking you in advance for your courtesy in the matter, I am,

Very respectfully,

EDWIN J. HOUSTON.

Prof. A. E. Dolbear in answer to the above kindly sent me in addition to a very full reply by himself, a number of letters received by him from scientific men, referring to the same subject, with permission to publish the same.

TUFT'S COLLEGE, COLLEGE HILL, Mass., Oct. 1885.

PROF. EDWIN J. HOUSTON:

My Dear Prof.:—I have taken great pains to learn what Reis did with his telephone and what is possible with it, and I think it possible that I have made many more experiments with it than Reis himself did. The whole interest in the present controversy centres in Reis's transmitter, as to whether it is, and was in Reis's hands, capable of so modifying an electric current, through the automatic action of sound vibrations, as to produce what is now called the undulatory current, and of transmitting articulate speech. Now the structure of Reis's transmitters is so well known that a detailed description is not needed. All of them (for he made eight or ten forms) were so made that sound vibrations of any sort should act upon a diaphragm, carrying an electrode, upon which rests with gentle pressure, either by a spring or by its own weight, another electrode, these being part of an electric circuit, the intent evidently being that the actual movements of these electrodes, when actuated by sound vibrations, should modify the strength of the current so that it should represent as nearly as possible the wave movements in the air. If Reis's apparatus was not *intended* to duplicate such air movements by changing the energy of the current by the transmitter, I can see no use for Reis's figures of compound sound waves and his extended explanations of them. Whether apparatus so made and used will so modify a current is simply a matter of fact and in no wise depends upon any one's theory of electricity, or sound, or molecular action, or of make and break of circuit. It ought not to be lost sight of, nor kept obscure, although every effort has been made to divert attention from it, that Reis's transmitter like every other kind of transmitter acts *automatically* when it works at all, and its individual vibrations cannot be controlled by any one. Whether there will be a make and break of contacts or not, depends upon the rate of vibration and the amplitude of vibration of the diaphragm. If the amplitude be great and the rate low, the electrodes will not separate, for the free one can follow the movements of the membrane. If the amplitude be small and the rate high they cannot separate; in either case there will be only a variation of pressure of the electrodes at the point of contact. So much is purely mechanical and automatic, but it needs to be said and emphasized, for, first: it is true; and second: because this was lost sight of by the courts, and has cunningly been evaded by those interested in the denial of Reis's claims to be considered as the inventor and maker of the first speaking telephone. Every one who has experimented with Reis's transmitter knows that it will transmit articulate speech, except a few, a very few, who have an interest in not knowing. I have known one such to find a convenient excuse for absence when he had good reason for thinking that by staying his expressions of opinion would have to undergo revision.

Now Reis invented a device which he called *The Telephone*. He described its structure so that others could make similar ones, and in addition he undertook to explain throughout its mode of operation, a work which it is impossible to complete even to-day with all the advance in the knowledge of electricity and mechanics. It is in his explanation of the mode of operation of the instrument that he speaks of making and breaking the current. It might fairly be asked how Reis could absolutely know that there was a make and break for every vibration supposing that it did actually occur. He could not prove it, and, as a matter of fact, it is mechanically impossible that it should make and break the circuit for every vibration for complex sounds.

Let us suppose that we are in Reis's room, where his apparatus is set up, and we ask him how it is to be used? He says to one at the transmitter "Make sounds of *any kind*, it will transmit them," and to the one at the receiver "simply listen at the receiver." The first sings and speaks, and the latter says he heard the singing and words. Ask Reis to explain how the thing is done and he talks about makes and breaks of the current at the movable contacts of the transmitter. But Reis, how do you know that it makes and breaks for every vibration when it is transmitting words? Reis didn't and couldn't know. What Reis was doing, was helping his auditors to an easy conception of the possibilities of his apparatus, and I submit that at this day his explanation is the shortest and simplest for any who are not somewhat skilled in physics. I am not saying that it is not possible to transmit speech by a make and break circuit for every vibration, because McDonough with his wheel has demonstrated that it can be done and has thus proved that Reis was right, if such a construction be put upon his words. What I am saying, is, that if Reis *intended* that his apparatus should make and break the circuit for every vibration, then he failed, for his apparatus won't do it. It works *automatically* when it works at all and does not depend upon the *intention* of the speaker to make and break for every vibration. In the Spencer case, Judge Lowell gave the famous decree that 100 years of Reis would not make a speaking telephone. The 100 years is up, however, and McDonough with his *make and break* wheel says *hello*, easily recognized by Profs. Young, and Brackett, and many others as well as by myself.

When Sir Wyville Thomson sent home from the *Challenger* his observations on *bathybius*, Prof. Huxley sought the first print to say that he was mistaken when he gave the substance its name and philosophical importance—an example which a $20,000,000 monopoly could not afford to have followed.

Again, it is admitted everywhere that there is no *mechanical distinction* between the Reis transmitter and the Blake transmitter, and that the efficiency of the latter depends upon the employment of carbon where Reis used platinum. Does any one think that Reis would have explained his device differently if he had used the substitute? or, that he would not have had a speaking telephone comparing well with any we have to-day?

It has been affirmed again and again that if Reis's transmitter will transmit now, it is because we apply knowledge to it which has been acquired since 1876. Take then a Reis transmitter that has not been touched since

1864, if such an one can be found, and connect it properly in circuit with a battery and connecting wire. If it be spoken to will it act microphonically or not? Any one having knowledge enough of the apparatus to be entitled to an opinion, who should say that it would not, would be entitled to admiration for his hardihood. If it will work microphonically it is because such action is *inherent in the mechanism* and not on account of any knowledge imported into it, and any such assumption is a fiction, warranted by nothing except the necessity for denying the right of the public to use that instrument for the purpose for which it was made. One may sing to it, may whistle or screech at it, but remember that if anyone hears a word from it the Bell Company is entitled to his head. "The law allows it and the court awards it."

But making no distinction between the description of a piece of apparatus and the explanation of its mode of operation, giving the merit of the invention to the man who properly explains it would make fine work throughout science. Let us see! When Crookes made and exhibited those wonderful tubes called *radiometers*, he explained their action as being due to the direct action of light upon the delicately-poised vanes. He *intended* that the impact of light waves should propel the vanes, and they certainly rotate as he also *intended*. Afterwards Stoney and others, better acquainted with thermo-dynamics than was Crookes, gave a more consistent interpretation of the motion, but I have yet to hear that 100 years of Crookes wouldn't make a radiometer. Is it because there was no $20,000,000 behind it? Brewster invented the kaleidoscope, but as long as he lived he explained its phenomena on the basis of the corpuscular theory of light. Brewster's claim was not denied. Was it because there was no $20,000,000 behind it?

If Daguerre explained the action of light upon his sensitive silver plate as being due to the formation of a solar salt upon it, the degrees of shade depending upon the amount formed, he was altogether wrong, but the one who explained the chemical action upon the plate, made no claim to the discovery of photography. Was it because there was no $20,000,000 behind it? Let one invent a new galvanic battery cell and describe it, telling what solids and liquids to use and their proper disposition in the cell. Let him explain that it is his *intention* that the ammonia shall combine with the zinc, and the chlorine be set free upon the carbon. The battery shows when it is set up, that that evidently was the intention, for the elements are placed in proximity and are free to *if they will*. The courts may declare that what he invented was what he explained, not what he made,—if there be $20,000,000 that wants the invention.

Grove invents a galvanic battery and describes its make-up, and explains its action on the *chemical* theory of electricity; Bunsen improved it by substituting carbon for the platinum and explains the whole on the *contact* theory of electricity, which is endorsed by Sir Wm. Thomson and many other physicists. What Grove had in mind was to produce electricity chemically, Bunsen had in mind the correct conditions for generating it, and his battery exemplifies it. A hundred years of Grove will never make a galvanic battery, if there be $20,000,000 that wants his invention.

Another point which has been made much of on one side, namely, that if

Reis had succeeded in transmitting speech, that it is incredible that no more should have been heard of it, and that it is extremely unlikely that such a success should have remain uncredited for so many years as to be almost lost sight of. But the answer is at hand. It is not denied that Yates, of Dublin, did transmit speech telephonically, in 1866, with his improved Reis apparatus, Did it attract any attention? Was it even chronicled? Why was no public mention made of it? Simply because it was considered a curious toy and not of commercial importance.

To sum up then, in my opinion:

1st. Reis invented a speaking telephone capable of transmitting words, that he intended it for that purpose and used it with success, for he says in his so-called *prospectus* when giving directions for using it "sing," "speak" He also says directly in one of his lectures, "*words were transmitted.*" This is also the testimony of a considerable number of those who were with him, Quinke, Messel and others. One of the most eminent scientific men in the United States said to me: "The testimony of Quinke alone is enough to settle that point."

2nd. That Reis's transmitter works in precisely the same way, while transmitting speech, as do the modern ones, namely by what is called *microphonic action.*

3rd. That the only difference of any importance between the Reis transmitter and the modern commercial one, is in the material, carbon being substituted for platinum for an electrode, which renders it more efficient but does not change the method of operation.

4th. That the main reason why Reis obtained no better results than he did, was due much more to the lack of sensitiveness in his receiver than to defects in his transmitter. The weaker vibrations though present, being so much diffused as to be often inaudible. The modern receiver is more efficient on account of its boxing. There is no principle or mode of operation in the modern telephone, which was not known and embodied in instruments made for the purpose twelve years before the famous patent of 1876. This patent could not have been for a *new art.* The Bell Company knows all this as well as anyone, and is in constant fear that the courts will find it out. Ask a Bell man: "What is a Reis transmitter?" and he will answer: "One that will not transmit speech." "What is a Bell transmitter?" Ans. "One that will transmit speech." "If a Reis transmitter transmits speech, whose transmitter is it?" Ans. "Bell's."

To show that I am not alone in my opinion upon these points I append the opinions of other scientific men in the country to whom I applied, asking them to state what their views were upon Reis's telephone, and give me permission to quote them. As will be seen, there are not two opinions about it any more than there are two opinions as to whether the earth is flat, though there may be here and there a man like "Parallax" in England who is stoutly defiant.

Yours truly,

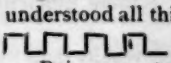
A. E. DOLBEAR.

PHYSICAL LABORATORY OF WASHINGTON UNIVERSITY,
ST. LOUIS, May 21, 1885.

PROF. A. E. DOLBEAR:

Dear Sir:—Replying to your question concerning the difference between the action of the Reis transmitter and the ones now in use by the Bell Company, I reply that I cannot see that there is any difference in the method or manner of working. It is a source of amazement to me that the courts have decided differently, and I regard it as a very great disgrace, arising I hope from ignorance.

I do not think that either Reis or Bell were perfectly successful in describing the working of the transmitter, but of the two Reis is ahead.

Reis describes clearly the character of sound-waves, and wishes to have these sound-waves act upon his transmitter so as to produce changes of a similar character in the electrical apparatus, in order that these sound-waves may be again reproduced by his receiver. He seems to have fixed his attention upon the magnetic field, or magnetic condition of his receiver, and knowing that a break in the circuit did not abruptly extinguish the current, by reason of the self-induction of the wire coils, and that the closing of the circuit was followed by a gradual rise to the maximum current, he thought a make and break between spring contacts would accomplish what he clearly saw was necessary. He knew also that similar retardation occurred in the magnetization and demagnetization of the iron core. He seems to have understood all this much more clearly than Bell, who draws lines like this  to represent the case of a make and break circuit.

Reis seems to have intended to produce wave-like changes in the magnetic condition of his receiver, and this is precisely what is necessary, *and it is precisely all that is necessary, in order to transmit articulate speech.*

When a circuit containing an electro-magnet is opened and closed, the changes in the magnetic condition of the magnet are necessarily wave-like, and Reis may have thought therefore that a make and break would serve to accomplish the result at which he aimed. But we know now that under the conditions which are supplied in the Reis transmitter, the wave-forms are not of the proper shape to reproduce speech if the circuit is opened and closed at the working contact. The fact is that when the Reis instrument does transmit speech, the circuit does not open and close, and whatever Reis may have thought about it, it did not make and break the circuit when it worked successfully in his hands. It worked by varying the resistance at the loose contact, precisely as the "modern" instruments work to-day. The result at which Reis aimed was to produce the proper variations in the magnet strength. He succeeded in doing this in an imperfect manner. But that he did succeed in doing it I cannot doubt. His main weakness was in the receiving instrument, which was not sensitive enough.

What I have written here seems so clear and evident to me, that I cannot avoid thinking ill of a man who says it is not true. Unless other considera. tions prevent, I class him among those who say the earth is flat.

I am not in any way financially interested in any kind of telephone, but I

think it is time for scientific men to speak out on this subject, and so far as I happen to know they are practically of one mind.

It is not very likely to influence the legal decisions, but it may at least relieve American scientific men of the disgrace of giving even tacit countenance to a monstrous imposition. Very sincerely yours,

FRANCIS E. NIPHER.

3208 RACE STREET, PHILADELPHIA, Pa., July 22, 1885.

PROF. A. E. DOLBEAR,

Dear Professor:—(1.) There *will* be a telephone report.

(2.) I had supposed, without pretending to be a specialist that there was but one way a telephone *could* work, and that therefore Reis had the idea which was made available later. I have not made that accurate historical research without which I simply should hold my judgment in suspense.

(Signed) Yours truly, LEONARD WALDO,
Yale College Observatory.

STATEMENT.

Having received a Reis instrument, same as "Fourth form" described in Reis's own paper "On Telephony" in the annual report of the Physical Society of Frankfort-on-the-Main for 1860–61, (see p. 20 of Thompson's "Reis Inventor of the Telephone," I had no slight curiosity to know whether it would or not transmit speech.

I connected my lecture room with the Physical work shop using about twenty lbs., of 18 office wire, one Grenet cell, and two Bell receivers in circuit. One of the receivers was located at opposite end of line in shop, while the other and Reis transmitter with the battery were on my table.

After securing fine *singing* adjustment (by *singing* I mean one that would cause the Bell receiver at my ear to hum freely when talking with the Reis) I found that my assistant in the shop could carry on conversation quite readily—so much so that we were both astonished at the results. He called others into the shop, and in more cases than one we fooled the hearers so completely that they supposed that we were using the regular Bell outfit at my end of the line.

We still use the circuit for communication between lecture room and shop without difficulty.

Surely no one who had ever seen a Reis Telephone could claim thereafter to have invented the system of transmission of speech by electric pulsations or undulations.

(Signed) JOHN B. DEMOTTE,
Prof. of Physics.
De Pauw University, Greencastle, Ind., July 21, 1885.

SHEFFIELD SCIENTIFIC SCHOOL OF YALE COLLEGE.
NEW HAVEN, Conn., June 3, 1885.

PROFESSOR A. E. DOLBEAR:

Dear Sir:—It is certainly my impression that Reis's telephone embodies all the essential features of the systems now used and that if it had been

generally known, the exclusive patents which have proved so valuable would not have been granted; but I am unable, under the pressure of annual examinations and much other work, to undertake to either write out a carefully formulated opinion, or to make experiments in a field which is now chiefly of a historical or technical interest.

Yours very truly,

(Signed) CHARLES S. HASTINGS.

OHIO WESLEYAN UNIVERSITY,
DELAWARE, O., June 30, 1885.

PROF. A. E. DOLBEAR, *Tuft's College, College Hill, Mass.:*

Dear Sir:—I have been experimenting with a telephone, made according to the description that Reis gives of one that he made. It is an exact pattern of the one described by Reis. I am irresistibly forced to these conclusions from all the knowledge I can gain on the subject, viz., that Reis did invent a speaking telephone, and that as he invented and constructed it, it is capable of transmitting articulate speech, and that it did so in Reis's hands, and that as a transmitter it substantially works in precisely the same manner as any modern transmitter does when transmitting articulate speech. Reis's invention, the telephone, was undoubtedly what he made, he probably did not fully understand its mode of transmitting speech, nevertheless he made a telephone that in my hands fully and completely transmitted entire sentences. Reis's description of the operation of his instrument is one thing and its work another in my opinion; his invention is the telephone, an articulate speech transmitter, and not a description of its operations.

I am, very truly yours,

(Signed) W. O. SEMANS,
Prof. Chem. and Physics.

COLUMBIA COLLEGE, N. Y., May 28, 1885.

A. E. DOLBEAR, Esq.:

Dear Sir:—In answer to yours of April 29th, I would say, that in my opinion the Reis transmitter, when made and adjusted as the maker intended, is capable of transmitting articulate speech, operating like the Blake transmitter, the action being microphonic, and differing only in efficiency from modern instruments of this class; in other words, Reis in my opinion invented a speaking telephone, operating with precisely the same kind of currents now so commonly employed, the defect of the apparatus being in the lack of sensitiveness of the receiver.

Very truly,

(Signed) OGDEN N. ROOD,
Prof. of Physics in Col. Col.

DEPARTMENT OF PHYSICS, CORNELL UNIVERSITY
ITHACA, N. Y., June 1, 1885.

My Dear Professor Dolbear:—I am under obligations to you for showing me, while you were in Ithaca last week, a genuine Reis by which, when used as a transmitter in connection with a Bell magneto telephone as a

receiver, conversation could be carried on with nearly the same facility as by the Blake transmitter. The experiment showed conclusively that the Reis telephone, with only platinum contacts, not only can transmit speech, but does so so clearly and distinctly that if we had not something better it would be considered a thoroughly successful transmitter.

Had Reis succeeded with his receiver as well as with his transmitter the speaking telephone would have been in universal use ten years earlier than it was.

Yours very truly,

(Signed) WM. A. ANTHONY.
Prof. of Physics.

PRINCETON, N. J., May 28th, 1885.

My Dear Professor Dolbear:—As to the matter we talked about, the case stands about thus in my opinion. Reis set out to make an instrument that would convey sounds electrically; there is no evidence that there was in his mind any limitation whatever as to the kind of sounds to be conveyed, and there is on the other hand considerable and conclusive evidence that he had in mind articulate sounds as well as musical tones. He constructed apparatus which would communicate musical sounds very well, and articulate speech partially; that is, he occasionally got speech through it: but not hitting upon *carbon* as the material of his transmitter electrodes, his success as regards articulate speech was not complete or satisfactory.

Being no business man, and looking at the thing from a scientific rather than a business point of view, he took out no patents, and made no attempts that I ever heard of to introduce his invention as anything more than a piece of interesting scientific apparatus. He did *publish* his results somewhat widely, and his instruments were put on sale as scientific apparatus.

His instruments, just as they came from his hands, will talk now, if manipulated carefully enough, and if *improved* by merely inserting a bit of carbon at the loose contact of the transmitter, would to-day answer satisfactorily for telephonic business; though of course any one would admit that the receivers and transmitters now in use are better than such an apparatus would be. But his *receivers* will any of them operate fairly well with our modern microphone transmitters, and his *transmitters*, fitted with carbon electrode are excellent, even judged by the latest standard.

The fact that he spoke of his transmitter as working by "opening and closing" the circuit, and did not enter into any discussion as to the question of the completeness of the "make and break" in the transmission of words, does not appear to me to justify at all any attempt to deprive him of the credit of his invention. Perhaps the question did not raise itself in his mind, and perhaps it did; but however that may be, he invented an apparatus that would talk—rather capriciously it is true, for want of carbon, but still, when exactly adjusted, it would talk until the adjustment was disturbed. Nor, I think, can there be any question that the action of his apparatus, when thus talking under successful adjustment, is precisely the same as it would be if one of the electrodes was tipped with carbon, and the same also as the action of any of the ordinary carbon transmitters now in use.

As to the precise nature of the action at the "loose contact" of a transmitter, I think no one is yet entitled to speak with confidence. That it *may* consist of actual "makes and breaks" of the current in the ordinary acceptation of the term is proved to my satisfaction by McDonough's revolving wheel experiments; that it *may* consist on the other hand in a rapid variation of the strength of the current without complete "makes and breaks" is of course possible, since in the magneto telephone this is unquestionably the way the current acts. But as I view the matter, *whatever* the action may be, no man has a right now to claim exclusive ownership of it for having discovered an explanation of it, even if his explanation should turn out to be more accurate and exact (which need not yet be admitted) than that of the man who first used that action for the transmission of words. If Mr. Bell's explanation proves correct, well and good, he deserves *scientific credit* for it, but not *patent right* in it, as against Reis.

I do not know that this letter will answer your purpose, but if you can make any use of it, it is quite at your service to do what you like with it.

Very truly yours,

(Signed) C. A. YOUNG.

U. S. DEPARTMENT OF AGRICULTURE.—DIVISION OF CHEMISTRY.

WASHINGTON, D. C., May, 21, 1885.

PROF. A. E. DOLBEAR, *College Hill, Mass.*

Dear Sir:—I have had the pleasure of testing a model of the Reis telephone, and was surprised at the distinctness with which his transmitter allows the passage of articulate speech. In the trial which I made of the instrument, the distinctness of the transmitted conversation was as marked as that of the ordinary telephone.

It seems to me that the only difference between the Reis transmitter and those of the modern telephone is in efficiency and not in principle. The trouble which Reis encountered in his experiments I am now convinced, was in his receiver and not in his transmitter. Had he been provided with a receiver as delicate as those now in use, the telephone would have been a commercial success twenty years ago.

The transmitter which was used in the trials made in my presence was an exact reproduction of the one described in Reis's original drawings; and the result of the experiment leaves no doubt in my mind that Reis was the inventor of a speaking telephone.

Messrs. Richardson and La Dow, who were with me during the experiment were also much pleased with the excellent action of the instrument.

Respectfully, (Signed) H. W. WILEY.

ANN ARBOR, Mich., June 17, 1885.

PROF. A. E. DOLBEAR:

My Dear Sir:—I can confidently assure you that I have heard speech transmitted in a satisfactory way by means of a Reis's transmitter. The instrument was a careful copy of one of the forms figured in Thompson's

book on Reis's telephone, and the results were nearly or quite as satisfactory as I usually obtain with more recent forms of patented instruments.

Sincerely yours,

CHARLES K. WEAD,
Prof. Physics, Univ. of Mich.

NORTHWESTERN UNIVERSITY,
EVANSTON, Ill., Oct. 10, 1885.

PROFESSOR A. E. DOLBEAR,

Dear Sir:—Respecting the Reis telephone, the evidence appears to me to be entirely conclusive on three points:

First. The Reis telephone, or a faithful copy of it, transmits speech to-day, "with a distinctness sufficient for everyone" to understand plainly.

Second. It transmitted during the lifetime of Reis himself. Of this we have evidence from contemporary printed accounts of its performance, and from *ear-witnesses*, if the word may be allowed.

Third. Reis designed the "*Telephone*" to transmit speech. His own account of "Telephony," published in 1862, is unmistakable on this point.

Philip Reis conceived the idea of transmitting speech and music by Galvanic Electricity, and constructed an instrument that actually did this, even though the laws of the composition of vocal and other sounds were not at that time well understood; and he should certainly have the credit arising from so great an invention.

Very truly yours,

(Signed) H. S. CARHART,
Prof. of Physics.

BOSTON, Oct. 10, 1885.

PROFESSOR A. E. DOLBEAR,

Dear Sir:—In reply to yours asking for information concerning my knowledge of Philipp Reis and his relation to the telephone would say that I had, previous to 1881, become so much interested in the subject that, happening to be in Germany, I resolved to visit the field of his labors that I might not only satisfy my curiosity but also judge for myself from the testimony of living witnesses, and from apparatus which Reis has left of the character of the work accomplished by him. Near the centre of the small village of Friedrichdorf, and directly opposite the Post Office, stands the modest house where Philipp Reis formerly lived and which is still occupied by his family. There remain many evidences of his former presence. In the casement of the sitting-room window, electrical binding posts with wires leading to a room in the rear may still be seen. Placed there by Reis himself and used by him in making probably the greater part of those important investigations in the endeavor to perfect his apparatus for the transmission of speech. This was his aim and anything short of that he considered of little importance—so said Mrs. Reis. A short distance further up the main street stands the Garnier Institute, where Reis as a teacher displayed a wonderful ingenuity in devising apparatus for illustrating the usual experiments in Physics and also evinced, as shown by several pieces in the collection, an originality in invention and research of a very high order.

Prof. Leon Garnier, Principal of the Institute, said he had often witnessed Reis's telephone experiments and repeated many words and sentences which he himself had heard through the apparatus.

I was next introduced to Herr Henry Holt. He thus related his first successful experience with the telephone. "I had been listening a long time, and heard nothing intelligible, when suddenly I plainly heard the words, '*I am through; come up.*' I went up, and was considerably surprised to find that that was exactly what Reis had said, and he then explained to me that the speech had been transmitted by the electric current." Mr. Holt said Reis was at the time highly elated over it. After that, he listened with much greater faith, and hence with closer attention, and, on many occasions, heard words and sentences. Reis was evidently sorely tried by the incredulity of those who, in the earlier experiments assisted him, and who, consequently, were very careless and inattentive listeners. Many a joke did poor Reis encounter from his co-laborers and associates, but he eventually silenced them all; and, although they could not realize its importance, they yet recognized the fact that Reis had then made a speaking telephone, and that it was to him as the inventor of the speaking telephone, that the monument in the cemetery at Friedrichdorf was erected by the Frankfort Society. Many have, as you know, for selfish reasons, endeavored to belittle that testimonial by claiming that it was the invention of the *musical* telephone, which it was intended to commemorate. Owing to the difficulty of making such delicate tests before a popular audience, the transmission of musical tones was given prominence at his lecture. It was with much pleasure that I visited the very building and room at Frankfort, in which that famous first lecture of Reis on the telephone was given, and strolled through the garden, across which the wires, on that memorable occasion, were stretched.

The original manuscript in Reis's handwriting had previously been shown to me by Mrs. Reis; she still has it I believe in her possession.

At the shop and factory of Albert, philosophical instrument maker, I learned several interesting facts. The Reis transmitter known as the *collar box* pattern was shown to me by Mr. Albert and he said, as seems probable, that it was made previously to the *square box* and subsequent to the bored block pattern. It seems to me that this must have been the order of sequence. I feel sure that Reis did not employ Albert until after his lecture before the Frankfort Society where the *bored block* transmitter was used; moreover, Albert says he made the collar box pattern himself and this more nearly resembles the *square box pattern;* involves the same ideas; and seems like its crude beginning.

The *collar box* and the *square box* patterns were, however, not intended as superior instruments *i. e.* instruments from which Reis could himself obtain better results, but were so made because they were automatic in their action. At that time there was a call for his apparatus and Reis reasoned that an instrument which dispensed with such delicate adjustment as the *bored block* required would be better to put into the hands of the unskilled experimenter.

Mr. Albert said there was a great difference in the performance of the

transmitters even when made as nearly alike as possible. I have myself verified this experience of Mr. Albert. For example I have had a dozen of each of the parts of the *bored block* transmitter made and placed in piles by themselves each piece like its neighbor, and interchangeable like the parts of a Waltham watch. When set up, taking a piece from each pile, for each instrument, the transmitters could not be told apart except by the number stamped upon them. Upon testing them a great difference was observed in their performance. With some, talking could be transmitted at once, while others needed much adjusting and patience before they would do well even if they ever would. This explains why the various early writers concerning these telephones differ as to their capabilities. Some by chance obtained good instruments, others not so good although all seemed alike.

It was my good fortune, while in Europe, to obtain a pair of instruments which were exact fac-similes of those now held by the German Government and claimed to have been the first set sent out by Reis.

The transmitter was of the square box pattern and the receiver (the knitting needle pattern) corresponded to Pisco's minute description.

With these instruments I have at various times performed many hundred experiments. I have heard both words and unexpected sentences as plainly as with the best modern instruments. When so transmitting speech, the transmitter does its work in precisely the same manner as does the Blake, Edison, or other ordinary varying-contact transmitter. The current produced has variations precisely similar to the variations caused by carbon transmitters. By substituting a small piece of electric-light carbon for piece of platinum foil, which terminates one of the electrodes of the *bored blocks* transmitter, I have obtained an instrument as good and as practical as a Blake transmitter. Indeed, the latter is then but a close imitation of the *Reis bored block*. With a transmitter thus modified, the Reis knitting needle receiver is a good practical receiving telephone. Its tones are clear and articulation excellent.

As the result of my investigations and experiments, I am thoroughly convinced that the Reis apparatus can and in the hands of Reis did transmit articulate speech, and that Reis should and will go down in history as the first and original inventor of the Electric Speaking Telephone.

(Signed.) H. C. Buck,

Electrician, 70 Washington St., Boston.

Prof. A. E. Dolbear:

Dear Sir :—I tried in connection with Prof. Van Dyck the Reis transmitter (an exact duplicate of the instrument made by Prof. Reis as I am informed and believe) with an ordinary receiver, and was surprised at the ease and distinctness with which I could hear the sentences transmitted. They seemed at times as clear as though sent by the modern telephone, but the instrument required occasional adjustment. It seems to me there is no doubt that Reis invented a speaking telephone that worked on the same principle as the modern one and not by a make and break circuit, though I am not certain what his theory about it was. I think his telephone would have successfully

worked in the transmission of speech if his receiver had been sufficiently sensitive. The fault was chiefly in the receiver and not in the transmitter. The telephone of to-day is an improvement on his, but retaining the same principle on which his works—variation of current from variation of pressure.

Very respectfully,

(Signed.) GEORGE B. MERRIMAN,
Prof. Astronomy and Mathematics, Rutgers College.
New Brunswick, N. J., August 22, 1885.

COLLEGE HILL, Sept. 27, 1885.

PROF. A. E. DOLBEAR:

Dear Sir:—In reply to your request I will say that in the Spring of 1878, while studying for the degree of Master of Arts at Tuft's College, I undertook a series of experiments in telephony, much of my time being spent in working with Reis's transmitters.

The results obtained were by no means uniform, but very often whistling, singing, and *talking* were reproduced with great power and clearness.

No intelligent physicist can for a moment fail to perceive the close similarity in every essential detail of Reis's transmitters and the more improved instruments of modern date. Each consists of a diaphragm the vibrations of which alter the contact resistance of a point in an electric circuit.

The vibrations of the diaphragm alter the contact resistance at the given point by setting up a varying pressure at that point. This is all there is to the ordinary telephonic transmitter.

Secondary coils are merely accessories; they are not at all *necessary*. The assumption that carbon greatly alters the specific resistance under varying pressures is erroneous. It is true that the contact resistance of carbon points is more manageable than that of most other substances, but good transmitters can be made by employing contacts of almost any conductors.

There is no difficulty in making the unmodified Reis transmitter talk well with almost any good receiver.

The assertion that Reis instruments are necessarily "make and break" instruments can only be made by one financially biased or ignorant of physical laws.

That they do frequently "make and break" is true, but so does the Blake transmitter, if spoken to too strongly. It is far more difficult to adjust the voice to the Reis instrument than to the Blake, but when once the voice is adjusted the Reis talks.

The Reis receiver is not quite so satisfactory. His knitting needle receiver is mechanically poor. The needle should have been perpendicular to the sounding board not parallel to it. Yet in spite of this defect the knitting needle receiver will talk with any good transmitter, Reis's included, and with some of the more modern transmitters, I have heard very good talking.

Reis's electro-magnetic receiver was better; indeed it was identical in principle with Bell's 1876 form.

In conclusion I would say that in view of the historical evidence, in view of the testimony of prominent scientific men still living who are contemporaries of Reis, and in view of Reis's instruments themselves, it seems to me nonsense to assert that Reis did not talk with his instruments or that he did not design them to talk.

Very truly yours,

(Signed.) W. L. HOOPER,

Asst. Prof. of Physics, Tuft's College.

PRINCETON, Nov. 12, 1885.

PROFESSOR E. J. HOUSTON:

My Dear Sir:—An absence has prevented an earlier reply to your favor of Oct. 21.

(1) I have no hesitation in saying that in my opinion Reis was the inventor of the speaking telephone. No one who has carefully studied the literature of the subject can have failed to be convinced of the truth of this position, it seems to me.

(2) Actual experiment with apparatus constructed in accordance with Reis's description of his own apparatus, and with apparatus constructed by Koenig, and sold as an embodiment of Reis's invention, has in my hands transmitted speech and in substantially the same way as the Bell apparatus when employing a Blake transmitter.

(3) Bell has set up a distinction among currents and claimed the use of an undulatory current in the process of transmitting signals for the purpose of "multiple telegraphy" and subsequently he has claimed the use of such currents for the purpose of transmitting speech. The undulatory current was as old as the first experiments with dynamic electricity. It had been expressly spoken of and employed by others before Bell and for a use exactly the same as that for which Bell claimed it in his celebrated patent which is now sought to be made the foundation of the great monopoly! (See Varley's English patent). There can be no distinction in the nature of the currents employed by Reis and Blake, and there is no reason for any distinction between the current employed by Reis and Bell when his apparatus is used as a telephone.

(4) There is not the least reason to doubt that Reis did succeed as he says he did in transmitting speech; since it can certainly be done at present with his apparatus. And there is competent testimony that he did so succeed.

(5) The Reis-Legat receiver is a good one and might be employed to-day in commercial business. Indeed it contains everything which Bell's receiver contains and acts in precisely the same way. One merely has to employ carbon for the contact pieces of the Reis transmitter, instead of platinum, to have an apparatus with which speech can be transmitted with certainty and clearly. *The use of carbon is not the invention of Bell.*

(6) The modern transmitting telephones with variable contact are nothing but Reis transmitters with carbon substituted for Pt.

I have not the least hesitation about taking any one of the positions here assumed with reference to the so-called invention of Bell.

Yours very truly,

C. F. BRACKETT.

NEW BRUNSWICK, N. J., Nov. 14th, 1885.

PROF. E. J. HOUSTON;

Dear Sir:—Yours of the 5th duly received. Not having made any extended study of the telephone in its historical aspects, I have been debating with myself how to reply to your questions seriatim.

I conclude to state what I have done and heard, as matters of fact. I have made a Reis transmitter with thin copper plate and platinum contact point. With this articulate speech has been transmitted most unmistakably, a Bell receiver being employed to receive.

That no absolute break of contact between point and plate of transmitter occurred I inferred from my failure to observe induction shocks while operating. These shocks are painfully prominent when transmitting music in the usual way. Nor could any spark be perceived while transmitting speech. Hence I believe that my Reis instrument does not give zero as minimum of current while transmitting *speech*. So far as my opinion is formed, it is that the *onus probandi* rests with those who assert an essential difference between the Reis transmitter and those of other patterns which operate by producing currents of varying intensity.

I write, as I said, what I can hold to as matters of fact, and I hope you will find it as pertinent to your purpose as would be seriatim replies to your questions.

Yours respectfully,

F. C. VAN DYCK.

1346 SPRUCE STREET, PHILADELPHIA, Nov. 4th, 1885.

PROF. E. J. HOUSTON.

Dear Sir:—Having some time ago made a careful study of the Reis telephone, and the literature on the subject including his lecture in German, I shall be happy to answer your questions regarding his claim to the invention of the speaking telephone.

First. I most emphatically declare that in my opinion Reis was the original inventor of the speaking *Electric* Telephone.

Second. This question is somewhat analogous and must be answered in two parts. The Bell telephone as originally invented by Bell and used by him is a magneto-telephone in which the current is developed by the vibration of the iron plate in front of the pole of the magnet in the transmitter and is therefore unlike the Reis instrument. But the present telephone of Bell in which a battery transmitter is used in connection with the Bell receiver the electric current is "*manipulated*" (if I may use such a term) in precisely the same manner as in the Reis apparatus.

Third. This question is one which in my opinion no one can answer positively for the reason that we do not as yet know whether there is such a thing as a "current of electricity" or what takes place in a conductor during the passage of that force called electricity. Since this is so we can neither say what form this so-called current takes in its passage through or upon the conductor. Even if we assume that there is such a thing as a "current" and that it is capable of assuming a shape it is in my opinion not necessary for the transmission of articulate speech that this current should be an undulatory

continuous one and such as Bell describes it, but may be an interrupted one provided the interruptions in the continuity are so small as to bridge over the residual sensation of the ear *i. e.* $\frac{1}{16} - \frac{1}{164}$ of a second. Moreover this is *the* vital question in the law suits of the Bell Telephone Company against so-called infringers of the patent.

Fourth. The evidence of the contemporaneous literature on the subject as well as Reis's lecture, points indisputably toward the fact that he transmitted articulate sounds, and it is my opinion that with slight improvements in his apparatus Reis could have transmitted articulate speech.

Fifth. It is my opinion that the chief defect was in the want of sensitiveness in the receiver and not in the transmitter.

Sixth. The modern battery transmitter is identically the same as the Reis transmitter with carbon instead of platinum for one of the contacts. In particular I will instance the Transmitter of Berliner. of Boston, which was bought by the Bell Company.

Hoping that these answers will be sufficient for your purposes I will in closing refer you for further information to the expert testimony in the case of Bell *vs.* Clay, in which you will also find all the important papers of the Reis literature.

Very truly yours,

——— C. SEILER.

DICKINSON COLLEGE,
CARLISLE, Pa., Dec. 15, 1885.

PROF. EDWIN J. HOUSTON, *Phila.*

My Dear Sir :—Pardon my apparent neglect of your two communications in regard to the Reis Telephone. It was not oversight, nor altogether want of time, and in no degree indisposition, but I happened to be present in 1865 at the trial of Prof. Reis's telephone at Giessen, in Prof. Buff's lecture room.

My recollection is not very clear as to the details of the apparatus or of the testing of it, as I was at that time more interested in many other things, persons, and places, but my recollection of the impression made upon me and as it seemed to me, on Prof. Buff and the others, that it was interesting and curious, perhaps, but not likely to grow into anything of great practical value. The Bell telephone at first created somewhat similar impression, but having acquired more interest in electrical applications in meantime, and electrical science being so much more advanced than in 1865, I regarded it as involving greater possibilities than I had done in case of the Reis instrument. In looking at the latter now, I cannot but regard it as simply born out of due season, a little too early to be appreciated and wrought out into a practicable instrument.

In answer to your interrogatories I would say then: I believe that Reis invented *a* speaking telephone as early as 1865, and that he succeeded in transmitting articulate speech at that time, and at the time I attributed the defects of the instrument, and in that, perhaps, reflected the opinions of others present, to the variable character of the contact of the transmitter, that seemed to be unavoidable in any instrument for the purpose. Regretting the delay, and hoping the above may meet your questions.

I am, yours truly, CHARLES F. HIMES.

417 WALNUT STREET, PHILA., Nov. 21, 1885.

PROF. EDWIN J. HOUSTON,

Dear Sir: My replies to your queries are as follows:

(1.) In my opinion Reis invented an electrical speaking telephone, but he was not the first inventor of that class of telephones. An extended and critical examination of many certified records and repeated interviews with Antonio Meucci, now of Staten Island, N. Y., have convinced me that he produced a practical speaking telephone as early as 1857.

(2.) When the Reis instrument was operating as a speaking telephone, it worked substantially in the same manner as does the instrument known as the Bell telephone.

(3.) I have never succeeded in transmitting sound by the use of an undulatory current (produced in the manner described in the Bell patent) and in my opinion it is impossible so to do, consequently I consider that when the Reis instrument transmitted speech, it must have been by the use of a current dissimilar to the undulatory described in the specification of the Bell patent.

(4.) I can see no reason why Reis should not have occasionally transmitted words, and I consider the testimony relating to the performances of his telephone to be conclusive, especially when coupled with results which are occasionally obtained by the use of instruments made in accordance with the descriptions published contemporaneously.

(5.) The defects of the Reis instruments seem to be chiefly due to crudeness of construction of both transmitter and receiver, but chiefly in the receiver.

(6.) The "modern transmitting telephones of the variable contact type" are interrupters of the electric current. I have clearly demonstrated some time since that unless the current is interrupted, no transmission of speech (or sound) is possible; of course the interruptions must not be of such duration as to become evident to the ear, for in that case communication is prevented by the interposition of gaps which cut off a part of the representative impulses necessary to produce the desired sounds.

The replacement of one platinum electrode by a carbon point undoubtedly allows of a greater separation of the parts without an actual breach of contact, so that interruptions which would otherwise be of too great duration to allow of the transmission of a majority of impulses are bridged over by an elastic conductor of vapor of carbon.

The Telephone of Meucci, to which I have made reference, was very similar to the present Bell receiver, and was used both for transmitting and receiving. It can be readily demonstrated that the result of the successful use of this magneto-electric device is the production of an interrupted and not an undulatory current.

The ordinary contact transmitter produces an interrupted current by breaking the continuity of the conductor, whilst the magneto transmitter produces a precisely similar current by causing momentary cessations of the current in a continuous conductor. Interruptions of the continuity of the current is an essential to successful transmission of speech with either sort of apparatus.

Respectfully yours,

CHARLES M. CRESSON, M. D.

In concluding this brief and somewhat incomplete history of the articulating telephone and of the distinguished part taken therein by its originator and inventor Reis, the author trusts that despite the limited time which a busy life has somewhat grudgingly afforded him for the work, he has been able to show the singularly complete and masterly way in which Philipp Reis, the first and true inventor of the articulating telephone, solved the problem of transmitting sounds of all kinds by means of electrical currents. He will feel satisfied, if even in a slight degree, he has helped to hasten the time when Reis will be universally acknowledged as the man whose genius invented the most wonderful instrument of modern times.

CENTRAL HIGH SCHOOL,
Philadelphia, December 2, 1885.

"ELECTRICITY IN WARFARE."

BY LIEUTENANT B. A. FISKE, U. S. NAVY.

[*Lecture delivered before the* FRANKLIN INSTITUTE, *November 13, 1885.*]

The first practical plan for using electricity in warfare was devised and executed by Colonel Samuel Colt, the inventor of the revolver, who, in 1841, wrote to President Tyler, stating that he had invented an apparatus by means of which he could destroy in a moment the most powerful man-of-war, even though miles away, and asking that the Government give him opportunity for demonstrating the truth of his statement.

The truth of his statement he demonstrated a year later by exploding a torpedo under water in New York harbor by means of electricity. Following up this success, he totally destroyed by similar means an old gun boat named *Boxer*, and six weeks later, in sight of the President, General Scott and others, he destroyed a schooner in the Potomac, distant five miles. Congress at once appropriated $17,000 to continue his experiments and perfect his apparatus; and in two months from this time he blew up the brig *Volta* in New York in the presence of 40,000 spectators. All of these vessels were at anchor; but in the spring of 1843, Colonel Colt demonstrated the further value of his invention by blowing up a vessel while underway in the Potomac, he being at Alexandria, five miles distant.

These performances seemed in that day little short of magic, and their practical value was evident to many; yet they stopped short at this point, and were never resumed. Colonel Colt endeavored to get further assistance from the Government, but without success. For a variety of reasons, the authorities regarded his plans with disfavor, and Colt, disheartened and distressed, was compelled to abandon his invention just at the time when its success was assured but its details not perfected.

But the Russians caught his ideas, and in the Crimean War, we find the harbor of Sebastopol defended by torpedoes many of which were operated by electricity. A few years later, in our Civil War, the electrical torpedo was extensively used by the Confederates in the protection of their harbors. In the Franco-Prussian War, torpedoes were so successfully employed in the defence of harbors, that hostile ships did not even attempt to enter them; and in the Turco-Russian War, the mere suspicion that a harbor was defended by torpedoes was enough, in many instances, to keep a hostile fleet at a surprising distance, for the hostile fleet could not know just how far beyond a harbor the torpedo defence extended.

Since the experiments of Colonel Colt, the electrical torpedo has gradually improved, keeping pace with the progress of the sciences of electricity and engineering; yet the original plan is the basis of the most elaborate and perfect instrument, and to the brain of Colonel Colt we owe the surest defence we have for the cities and harbors of our extensive coast.

At the present day an electrical torpedo consists of a strong, water-tight vessel of iron or steel, which contains a large amount of explosive, usually gun-cotton, and a device for exploding this by electricity; and the most important form is that which is anchored in a channel, and made to explode when an enemy's ship passes near it. These torpedoes are usually called submarine mines.

In our war, most of these torpedoes were not operated by electricity, but by mechanical means, which consisted for the most part of levers protruding outside the case, and so connected with the explosive inside, that when a lever was struck by a passing vessel, a hammer inside was caused to fall upon a cap, just as when the trigger of a musket is pulled, a hammer is caused to fall upon the cap. These mechanical torpedoes were used with considerable

success by the Confederates, and they caused tremendous damage to the Union ships; but they had many defects, on account of which they have been almost entirely supplanted by the more complete, though much less simple, electrical torpedo.

One of the defects of mechanical torpedoes was the danger attending the operation of planting them; another was the danger attending the operation of raising them; another was the fact that it was impossible to tell whether they remained in order, save by the expensive and suicidal plan of seeing if they would explode; and still another defect was, that a mechanical mine did not know a friendly ship from a hostile one, but would sink either with absolute impartiality.

Now, it is clear that an electrical torpedo is free from all these defects, because it cannot be exploded unless a current of electricity be sent through it from a battery on shore or on board ship; so that the only thing to do when it is desired to make it harmless, is simply to disconnect the battery; and when it is desired to put the mine into operation again, the only thing to do is simply to reconnect the battery; moreover, the condition of the torpedo can at any time be determined by sending a very feeble current through it, even though the torpedo be miles away, and buried in water many fathoms deep.

In order to understand how electricity can explode a torpedo, it is sufficient to know that when a current of electricity goes through a wire, it heats it to some extent; and if the wire is small enough, the heat produced is sufficient to make it white hot. Clearly, if powder or fulminate of mercury be in contact with a white hot wire, the powder or fulminate will be ignited, and if this powder or fulminate be enclosed in a tight vessel, together with powder or gun-cotton, a tremendous explosion will ensue. Therefore, in order to explode a torpedo, the only thing necessary is to send a current of electricity through a very small wire, preferably of platinum, which is within the torpedo, and in contact with the explosive.

That part of a torpedo which includes this small wire and its connections, is called the *fuze*. In practice, the fuze is a separate thing, and is screwed into the torpedo case, the wire from the battery coming into the fuze through a water-tight gland, so that, after the fuze has been screwed in, the torpedo as a whole is water-tight, and may be left under water for months without injury.

If the explosive charge is wet gun-cotton, as is now usually the case, the fuze contains fulminate of mercury, and is surrounded by a small charge of dry gun-cotton. The heat of the fuze wire explodes the fulminate, the explosion of the fulminate causes the instant explosion of the dry gun-cotton; and this, in turn, causes the instant explosion of the whole charge of wet gun-cotton in the torpedo.

But it is evidently not sufficient to be able to explode a torpedo; we must also know when to explode it; that is, we must know when the hostile ship is in such a position that she will be destroyed if the torpedo is exploded. Clearly we can know this, if we have a chart showing the exact position of each torpedo, and have also an arrangement by which we can know at any instant the bearing of a ship coming up the channel from two stations properly situated. If the ship comes into such a position that she is in the line of one of the torpedoes as seen from each station, she is clearly on the intersection of those lines and is therefore directly over that torpedo; and the only thing necessary is to touch the electric key controlling that torpedo, thus sending an electric current through its fuze, and causing its instant explosion. Another way is to have the telescopes at the two observing stations so fitted that when both point at any torpedo, the current is automatically sent through that torpedo. Therefore, if the observer at each station keeps his telescope bearing on an advancing ship, electricity will do the rest, and the ship will sink when she comes within the radius of destructive effect of any one of the torpedoes.

But what can be done at night, or in a dense fog?

Evidently these systems will not answer then, because a ship cannot then be seen, and for this reason, torpedoes now are frequently made absolutely automatic, so that whether the time be day or night, or the atmosphere clear or foggy, the mere fact of a ship striking a torpedo, is sufficient to insure her instant destruction.

This result is secured by the use of what is known to electricians as an automatic circuit-closer; that is, a device which, when subjected to certain conditions, automatically bridges over the distance between two points which were separated, thus allowing the current to pass between them. In submarine torpedoes it is usual to employ a small weight, which when the torpedo is struck, is thrown by the force of the blow across two contact points, one of which

points is in connection with the fuze, the other in connection with the battery, so that the current immediately runs over the bridge thus offered and through the fuze. In practice, these two contact points are connected by a wire even when the torpedo is not in the state of being struck; but this wire is of such great resistance that the current is too weak to heat the wire in the fuze. Yet when the weight above mentioned is thrown across the two contact points, the current runs across this bridge instead of through the resistance wire and is then strong enough to heat the wire in the fuze and explode the torpedo. Now the advantage of having a wire of high resistance between the contact points instead of having no wire between them, is that the current which then passes through the fuze, though too weak to fire it, shows by its very existence to the men on shore that the circuit through the torpedo is all right.

But instead of having the increased current caused by striking the torpedo to fire the torpedo directly, a better way is to have it simply make a signal on shore, and at the same time throw in a firing battery. Then when friendly vessels are to pass, the firing battery can be disconnected, and when the friendly ship bumps the torpedo, the working of the signal shows not only that the circuit through the fuze is all right, but also, that the circuit-closer is all right, so that had the friendly ship been a hostile ship, she would certainly have been destroyed.

The action of the torpedo placed in a harbor and connected by a submarine cable to an electric battery on shore is thus shown to be quite a simple thing. But it should not be gathered from this that the protection of a harbor is a simple thing, or one that can be accomplished in a few days on the outbreak of war. It should be remembered that each torpedo contains from 100 to 1,000 pounds of gun-cotton, that hundreds of topedoes will have to be used, that the amount of gun-cotton required will be enormous and that it will be wanted in a hurry, but that the operation of making gun-cotton cannot be hurried; it must be remembered that to make the torpedo cases required, will consume much time, that the making of the fuzes is a matter requiring the greatest possible care and calculation, that the operation of properly laying down these heavy and yet delicate torpedoes in deep water even in the best possible weather is an operation requiring great nautical and

engineering skill and practice. Yet even after the best possible system of submarine mines has been laid down, it will be of no use, unless an enemy's boats can be kept from countermining, and unless the operating rooms be furnished with the best instruments, and thoroughly protected against capture, by fortifications, guns and ships. It is no uncommon thing to hear men of intelligence airily say, "Oh, in time of war, we can defend our harbors by torpedoes." I do not think I am exaggerating, when I say it would take a year to put the torpedo defences of our harbors into proper shape, even if Congress were to appropriate the money to-morrow, and after that, a corps of men would have to be formed and thoroughly trained in laying down and taking up torpedoes and cables, making splices in submarine cables, testing circuits, managing electric batteries, etc.

In order to detect the presence of torpedoes in an enemy's harbor, an instrument has been invented by Capt. McEvoy, called the "torpedo detector," in which the action is somewhat similar to that of the induction balance, the iron of a torpedo case having the effect of increasing the number of lines of force embraced by one of two opposing coils, so that the current induced in it overpowers that induced in the other, and a distinct sound is heard in a telephone receiver in circuit with them.

As yet this instrument has met with little practical success, but its principle being correct, we can say with considerable confidence that the reason of its non-success probably is that the coils and currents used are both too small.

Besides these stationary topedoes or mines anchored in harbors, there is another class called spar torpedoes, which are carried on spars protruding from ships or boats, and which consist for the most part of cases of steel holding about thirty pounds of gun-cotton and fitted with electric fuzes, similar to those for exploding submarine mines. The torpedo on the end of the spar is connected by insulated wires with an electric battery in the boat or ship, and it is designed to be shoved under a hostile ship by a determined effort and exploded there. The current is sent through the fuze by pressing an electric key at the proper moment; or a simple automatic circuit-closer may be put inside the torpedo, so that when the torpedo strikes the ship, a break in the circuit is automatically bridged over in the torpedo, thus allowing the current to heat the platinum wire in the fuze and explode it.

Still another class of torpedoes are movable torpedoes.

These contain not only explosive and means for exploding it, but also machinery for moving the whole through the water and for steering it. A movable torpedo is therefore really a torpedo boat and torpedo combined.

In one class of movable torpedoes, such as the Lay torpedo, the motive-power is usually carbonic acid gas, or compressed air, the steering and firing being done by electricity. One wire usually suffices, a simple step-by-step device accomplishing the operation of sending the current through different circuits in the boat, the current through one circuit causing the throttle of the engine to open, the current through another causing it to close, another putting the helm to "starboard," another putting the helm to "port," another firing the torpedo, etc. Therefore, the operator on shore, or on board ship, can, by moving his switch in the proper manner, cause the torpedo boat to go ahead, stop, turn to the right or left, in such a way, as to go directly towards the object of attack, and then explode in contact with her bottom.

In another class of movable torpedoes, the electric current not only steers the boat, but it also propels it, there being an electric motor or engine inside which, when supplied with the requisite current from an electric machine on shore, or on shipboard, revolves rapidly, thereby causing the propeller of the boat to revolve, in the same way that a steam engine causes the propeller of a steamboat to revolve. The current for steering may either be sent along a separate wire, which may be inside, the other one, or a device may be used, by which one wire will suffice for everything.

Movable torpedoes being usually cigar-shaped, so that their section is circular or nearly so, the electric motor for an electric movable torpedo, which will most nearly fit the space intended for it (in other words, the shape which permits the largest size for a given space), is clearly one in which the distance from the centre of the armature to the outside of the magnets is constant, so that the field magnets form nearly a circle embracing the armature. The exterior form of the motor, called the Griscom motor, evidently seems to fulfil this condition well.

The most successful electric movable torpedo thus far tried is the Sims torpedo, with which experiments have been conducted under

General Abbot's superintendence for some time, and with very good results. Now as all men-of-war and all forts are to be supplied with means for generating electricity on a large scale, it is clear that an electric movable torpedo can be easily adapted to naval and military requirements, the mechanism of the torpedo being exceedingly simple, and the only thing to be done, to put it into operation being to connect it to a suitable electric machine, and introduce a key-board, by which the direction and strength of the current can be controlled. The torpedo will then be ready to move at any instant, and will have a supply of power practically inexhaustible.

Recent experiments in England have shown that the Whitehead torpedo, over which control ceases after it is fired, is not so formidable a weapon when fired at a ship under way, as many supposed, for the simple reason that it can be dodged. Now an electrical torpedo, over which control is exercised while it is in motion through the water, cannot be dodged, provided it be given sufficient speed.

For effective work against ships, capable of steaming fifteen knots per hour, the torpedo should have a speed of twenty knots. Now, there is no theoretical difficulty in the way of doing this, for a speed of eleven knots has already been recorded (though an electric torpedo to get this speed would have to be larger than a Whitehead having the same speed), and it may be conceived that a torpedo carrying, say fifty pounds of gun-cotton, capable of going twenty knots per hour, so that it would pass over a distance of 500 yards in about forty-five seconds, and yet be absolutely under control all the time, so that it can be constantly kept pointed at its target, would be a very unpleasant thing for an enemy to meet.

Our Civil War introduced another use of electricity into warfare, and gave birth to the art of military telegraphy. At first, the telegraph was used only communicating along the regular telegraph routes, but eventually a corps of Military Telegraphers was formed, and instant communication became possible between detachments in the field. The advantages of the telegraph in conveying information and orders with despatch was found to be so great that foreign nations took the hint, and to-day a telegraph train is essential to all armies. No well-equipped force in the world is without means for rapidly connecting, by telegraph, dif-

ferent headquarters with each other and with the different parts of an army, and in the Franco-Prussian War it was the telegraph, combined with the railroad, which made possible that wonderful speed and certainty of mobilization and manœuvre that caused the swift destruction of the armies of France.

In military telegraph-trains, miles of wire are carried on reels, in specially-constructed wagons, which carry also batteries and instruments, some of the wires being insulated, so that it can rest on the ground, and thus be laid out with great speed; while other wire is bare and is intended to be put on poles, trees, etc. For mountain service, the wires and implements are carried by pack animals. Regularly trained men are employed, and they are drilled in quickly running lines, setting up temporary stations, etc. In the recent English operations in Egypt, the advance guard always kept in telegraphic communication with headquarters and with England, and after the battle of Tel-el-Kebir, news of the victory was telegraphed to the Queen and her answer received in forty-five minutes.

The telephone also has been used in military operations, and with great success, having an evident superiority over the telegraph for some purposes. One use of the telephone, in fact, is to assist the telegraph in cases where, by reason of the haste with which a line has been run, the current leaks off, so that the receiving instrument will not work. The only thing necessary is to use a telephone to receive the message, and to use as a transmitter a simple buzzer, or automatic circuit-breaker, controlled by an ordinary key. In many cases where the ordinary receiving telegraph instrument refuses to work, the more delicate telephone thus used will work very satisfactorily.

(*To be Continued.*)

An Inglorious Columbus.—Edward P. Vining has published a volume of more than 700 pages devoted to the task of proving that Hwuischan and four other mendicant Buddhist monks discovered America in A. D. 458. Many preceding authorities, which are quoted largely, have noticed or translated Hwuischan's recital. Many resemblances are pointed out between Buddhism and the worship of Quetzalcoatl, parallelisms between the representations of that God and those of Gautama-Buddha, with some curious word-likenesses, and certain Mexican traditions, which seem to contain intimations of Hwuischan's visit.—*Amer. Naturalist, Oct., 1885.*

RAPID TRANSIT AND ELEVATED RAILROADS, WITH A DESCRIPTION OF THE MEIGS ELEVATED RAILWAY SYSTEM.*

BY FRANCIS E. GALLOUPE, M. E., BOSTON, MASS.

It would be difficult in a paper of reasonable length to treat a subject having so wide a bearing as that of rapid transit, with the exactitude and thoroughness of detail which might be expected in a technical article. The following notes are therefore with hesitation submitted, in the hope that the incomplete form and in some cases the mere suggestions which only can be presented within the limits of this paper, may be accepted in place of a more extended treatise.

The modern demand for increased facilities of transit is twofold. (1.) There exists an imperative need of better means for the conveyance of passengers within all our large cities, making the problem an universal one, although its attempted solution has thus far been local. (2.) There is the more general demand for more rapid means of communication between cities and important centres of population or business.

It is the present purpose to show what the existing requirements are, as indicated by their gradual development, for obtaining with safety a higher speed of transit, and how the problem may be met as it arises, first, locally, and then for transportation through longer distances.

The endeavors made to supply these wants are seen on every hand. Probably most would agree that the time of increased facilities for transit is coming. The world will never go back to slower speed. The tendency is indeed precisely opposite; that is, to save time, shorten working hours, and to concentrate the volume of transactions in centres of business or of trade. Whatever this progress of business and of life demands will be developed and put in practical use.

* A paper read at the Boston meeting, 1884, of the Amer. Soc. Mechanical Engineers, and reprinted from advance sheets of the *Transactions*.

Fifty years ago there existed only the very beginning of the present great development of the surface railway system, which has cost in the United States alone nearly $7,000,000,000, and employing 300,000 men, with an extent at the end of the year 1884, of 125,379 miles.* They transported last year 334,814,529 persons, and earned in gross $770,684,908, with interests and dividends paid, to the amount of $269,939,137.

Previous to this the most rapid methods of transit, still within the memory of older men now living, were only post-riding and the now primitive stage coach Not even the horse car had been invented. Later on, the horse railroad system took its place in the streets of our principal cities, and although not developing much increase of speed, its great convenience, as well as the economy shown by the introduction of the principle of carrying passengers by rail, as compared with any other method of land transportation, has caused the growth of this system to the extent of many miles of track and great perfection of detail. In Massachusetts, the present extent of the street railways is 310 miles, as compared with 2,851 miles of steam railways in the State; their value $12,410,631, carrying 94,894,259 passengers in 1884, and employing 3,846 men and 8,996 horses, as compared with about 16,000 employés on street railways in the whole country.

The horse railroad has had so important an influence in the building up of suburbs and extension of the growth of cities as seemingly to have become an absolute necessity; yet so great are the present objections in blocking the streets, failing to supply sufficient accommodations to the public, and loss of time by the delays incurred by passengers, that in the East, at least, it is becoming the general opinion that its limit of capacity and usefulness has been reached nearly if not fully.

While this system has been growing and other methods of obtaining relief from the crowded state of the streets and the consequent retarding of transit have become established, such as the London underground railway and the Vienna depressed railways, a system of elevated railways has been developed in New York

* From Poor's Manual of R. R.'s, 1885. Cost of Roads and Equipment, $6,924,554,444. First Railroad completed in Massachusetts, 1827; first locomotive run, August 8, 1829.

City, of which the results attained in the short period of time since 1872 have been extraordinary. Not only have these demonstrated the fact, not before proved or deemed hardly practicable, that a complete steam railroad system could be run upon the tops of a line of posts set in the streets, as in the Bowery line, with entire safety, speed and convenience, but the permanent success of the principle has been, I think, fully demonstrated. A short statement of their progress is inserted, from a recent paper. "During the first year the roads carried 170,000 persons, and during the past year nearly 100,000,000." "The first year's earnings were $17,000; last year nearly $7,000,000." "There was a steady progress each year." "The aggregate earnings since the road was first built have been $32,000,000; the aggregate passengers carried, $44,000,000."

Such being the facts, let a moment's glance be given at the local conditions existing in cities. Experience has shown that ease of communication in the transaction of business requires its concentration into the least possible space. A street too wide for business purposes is more detrimental than one too narrow. Th result has been the erection of five, seven and even nine-story business blocks, which, with the general introduction of fast running elevators, supply the demand for offices and warerooms, and are more valuable for business purposes than lower floors farther removed from the business centre. Now, with this great concentration and consequent increase in the volume of business through the streets, the capacity of the streets themselves has not been increased proportionately.

The result has been a blocking of the streets to a large extent, and the obvious remedy, if the height of buildings is doubled, is to have two-story streets, so to speak, *i. e.*, to relieve their crowded condition and divide the travel by some form of elevated railroad which shall take from the surface that portion of it which desires merely transit as quickly as possible, and thus relieve the one portion from its block and convenience the other.

We must either have rapid transit *upon the surface, under it, or above* the surface of the ground. The first is impracticable, for reasons to be shown later on, while the second is open to the same objection, on account of the limited field available caused by its

excessive cost.* For general usefulness, the only feasible method is the third.

Objections to this remedy have been of two kinds: (1.) The alleged damage to property adjacent to an elevated line of railway; and (2.) The sentimental one of injury to architectural features of the buildings. The first should be at once recognized where real damage exists, and met so far as practicable by the road. A new element has been introduced with the elevated railway, disturbing the existing business relations and property interests, which latter cannot defeat the railroad, but which must be readjusted after the introduction of this new element. The injury done in places, whether the abuttor's land is held to end in the edge of the side-walk, as in New York law, or extends to the centre of the street, should be compromised between the railroad and property interests, in equity, by the payment of damages, in case either of direct damages by land taken, or of consequential damages, if proved that the rent or income from the property is thereby diminished; but these cases are only incidental in comparison with the great and lasting benefits to the public at large. As to the second objection, it may be said that the demands of transit should be first met, with as little loss in other respects as possible. The primary use and purpose of the streets is for transit, and not for the display of the architectural features of the buildings lining them.

Opposition to these necessary facilities for transit, while somewhat surprising when the great benefits to be derived from them are considered, is yet to be expected when we review the history of the introduction of railroads to supersede the turnpike and the stage coach, the introduction of the horse railways even, or that of any of the great improvements, such as many in the progress of manufactures, which have destroyed the value of some class of property which they supersede. All such must, in the end, give way to the public need.

While it has been found that the elevated system is best adapted for long-distance travel, *i. e.*, for distances exceeding a mile, the reverse is true of the horse railway, which will still be found better

* The proposed underground railway for Broadway, New York, is estimated to cost from $800,000 to $1,400,000 per mile, for single and double tracks, respectively.

fitted for the accommodation of some portion of the short-distance passengers than even the elevated railway. Where the time required for conveyance is short, and speed, therefore, not an object, considerations of convenience will still lead the short-distance passenger often to prefer to step upon the cars of the horse railway, which goes directly where he wants to go, instead of climbing up a flight of steps into an elevated railway car, which may not leave him so nearly at his destination; and especially will this continue to be the case if, as now seems likely, its service becomes improved by the use of electric motors, in the near future.

For the increase of transit facilities, certain definite requirements should be met in any successful system. These may be regarded as those of, (1.) *safety;* (2.) *speed;* and (3.) *convenience and economy.*

The leading features of the surface railway system, viz.: (1.) *the rail and car*, for the reduction of required motive-power and dead weight carried per passenger to their least amount; and (2.) *the truck system*, having independent moving trucks, coupled, supporting upon them the platform and body of the car, should be retained.

Under the requirements for *safety*, should be noted: (1.) safety from derailment, since next to railroad accidents occurring to persons crossing or walking upon the tracks, which are not reported, more than one-half of all reported railroad accidents are from this cause; (2.) safety from obstructions upon the track. These consist of passing teams, tresspassers and cattle, rocks and timber falling upon it, wash-outs, which are of the nature of obstructions; in winter, the blocking of the tracks by snow, drifting of the same, and many other causes resulting from railways built at grade, or upon the surface of the ground; (3.) an efficient brake system should be provided that will act automatically should the cars break apart or other derangement occur; (4.) appliances to give the engine-driver positive and absolute control not only of the engine, but over the movement of the entire train.

Among the requirements for any material increase of *speed*, are, (1.) those insuring at least equal safety to that now existing under the increase proposed, such as holding the truck upon the rails by flanges or their equivalent, so that no derailment can possibly

occur by the trucks lifting or jumping away from contact with the rails; (2.) the centre of gravity of the engine and cars should be lowered and the stability of rolling stock increased, to prevent strains which would overturn them; (3.) more secure attachments between the truck and car body should be provided, to prevent the momentum of the car body from breaking away from the former; (4.) there should be provided an improvement in the design of motive-power, especially by the use of independent means for producing adhesion of the driving wheels to the rails; or a controllable and variable adhesion, not dependent upon the weight of the engine for the pressure of the driving wheels upon the rails; (5.) a consequent saving of weight both in engine and cars, with the same power of engine, and reduction of the dead weight carried per passenger, should be reached; (6.) for speed, a clear line to be provided, with no crossings at grade, and the use of an efficient block system.

For the attainment of *convenience and economy* the system used should be adapted:

(1.) For curves of shorter radius than have been heretofore practicable, especially in cities, where streets are narrow; and for through lines, a better allignment as to grades and curves, made possible frequently only where the track is raised above the surface. (2.) For economy in repairs, by possessing freedom from wash-outs or settling of the ground, and from the decaying of cross-ties.

It will be seen that most of the above requirements can be met and the result in view reached only by the employment of an elevated system. It is the belief of the writer that all steam railroads, excepting perhaps those only for freight, having speeds of less than ten miles per hour, should be elevated from the surface of the ground, because of the many advantages of such a construction, as will be shown more fully in the further discussion of this subject. In Massachusetts, a resolve of the Legislature,* referred to the Railroad Commissioners, looking to the feasibility of a gradual abolishment of all grade crossings in the State has already been

* "*Resolved*, That the Railroad Commissioners examine and report to the next Legislature upon the subject of providing for the gradual abolition of grade crossings in cities and the populous parts of towns." [Approved, April 19, 1884.]—*Report of R. R. Coms., 1885.*

passed, and this may be regarded as a first step in the direction indicated.

To show that many or all of these conditions may be fulfilled in concrete form and may exist practically, the problem will be illustrated by the selection and brief description of one of the several distinct systems, each containing some excellent features that have been proposed, namely, that of the Meigs elevated railway system, now under construction in the city of Cambridge, Mass.

This plan, invented and developed by Captain J. V. Meigs, of Lowell, Mass., as the result of over ten * years' careful study of the surface roads, their advantages and defects, is unique in that it is a complete system, one part absolutely depending upon the others, and having little or no analogies in the surface roads.

It may be regarded as a development from the New York elevated system, taking for its starting point the fact only that a railroad can be built and successfully run upon a single line of posts.

(*To be Continued.*)

RED TWILIGHTS.—M. Hirn sends to the French Academy a notice of observations from his observatory at Colmar, and expresses his surprise at finding that the redness originated at a height far above the ordinarily supposed height of the atmosphere. Without positively committing himself to any hypothesis, he thinks that electricity alone would have been capable of maintaining the extremely rare materials at such a height, if we suppose: (1.) That the extreme layers of our atmosphere possess a powerful specific electricity, and (2.) That the materials were themselves projected with an electricity of the same name.—*Comptes Rendus, Aug. 24, 1885.*

ALLOYS OF COBALT AND COPPER.—The alloys of cobalt and copper have a red color, and a fine silky fracture which resembles that of pure copper. They possess a remarkable ductility, malleability and tenacity; they can be easily forged and rolled when hot, but they cannot be tempered. They are obtained by melting copper and metallic cobalt in a crucible under a flux of boric acid and charcoal. G. Guillemin submitted some specimens to the French Academy, prepared from red electrolytic copper and an alloy rich in cobalt and copper with some nickel and iron. The alloys, which he has especially studied, contain from one to six per cent. of cobalt. The alloy with five per cent. of cobalt is particularly interesting for its useful qualities. It is as inoxidizable and malleable as copper, and as tenacious and ductile as iron. It can be used in the manufacture of rivets, fire-boxes for locomotives, tubes, and a great variety of braziers' work.—*Comptes Rendus, Aug. 10, 1885.*

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* Application for patent filed May 16, 1873; issued May 11, 1875. Earliest notes made in 1867 or 1868.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, December 16, 1885.*]

HALL OF THE INSTITUTE,
PHILADELPHIA, December 16, 1885.

MR. W. P. TATHAM, President, in the Chair.

Present—133 members and five visitors.

Sixty-five persons were reported as having been elected to membership since the last meeting.

The Committee to which had been referred the preparation of a memorial of the late JOHN W. NYSTROM, presented the following report, which was accepted and ordered to be spread upon the minutes, viz.:

"During the year just closing, we have to note the death, at the age of sixty-two years, of Mr. JOHN W. NYSTROM, for many years an active member of the INSTITUTE.

"Mr. NYSTROM was a native of Sweden, and there received a collegiate and technical education. He became a member of this INSTITUTE in the year 1850.

"Mr. NYSTROM was a frequent contributor to the JOURNAL OF THE FRANKLIN INSTITUTE, and participated actively in the discussions incident to the introduction of screw propellers for steam marine service.

"He also edited and published several scientific works, prominent among which are his 'Steam Engineering' and his 'Handbook for Engineers,' the latter has run through several editions and has a place with mechanics among standard books of ready reference; he invented a calculating machine and a number of minor improvements in steam engines.

"Mr. NYSTROM originated and proposed to publish and introduce a new system of enumeration instead of the decimal system, in which seven and fifteen were the highest integral figures instead of nine; he also devoted considerable attention to a new system of musical notation, neither of which, though showing great ingenuity and clear perception of the defects of existing systems, could be brought into use in view of the almost universal hold of the present systems.

"The readiness with which he submitted new symbols in his engineering works indicates the inclination and aptness of his mind for concise expressions.

"Mr. NYSTROM's forte and pleasure was in making mathematical formulæ, with which he was ever ready.

"He was an industrious member of the Committee of Science and the Arts, and will long and pleasantly be remembered by the members of the

committees with whom he was associated, as an honest and ready disputant, a cheerful and most untiring worker.

(Signed) "H. R. HEYL, *Chairman*,
"WM. BARNET LE VAN,
"S. LLOYD WIEGAND."

The following nominations for officers, to serve respectively for the term set opposite each name, were made:

For *President* (to serve one year), ... CHAS. H. BANES.
For *Vice-President* (to serve three years), ... FRED'K GRAFF.
For *Secretary* (to serve one year), ... WM. H. WAHL.
For *Treasurer* (to serve one year), ... SAM'L SARTAIN.
For *Auditor* (to serve three years), ... WM. A. CHEYNEY.

For *Managers* (to serve three years):

FRED'K FRALEY,	WM. P. TATHAM,	WM. H. GREENE,
PERSIFOR FRAZER,	WM. H. THORNE,	CHAS. H. HUTCHINSON,
WM. HELME,	JOHN J. WEAVER,	WM. D. MARKS,
EDWIN J. HOUSTON,	WM. L. BOSWELL,	SAM'L R. MARSHALL,
ENOCH LEWIS,	GEO. V. CRESSON,	E. ALEX. SCOTT.

Mr. WM. SELLERS made some appropriate remarks touching the many and valuable services rendered by the retiring President, and, in conclusion, offered a motion tendering him the thanks of the INSTITUTE. The motion was numerously seconded, and, being put to the meeting by the Secretary, was carried unanimously.

Prof. EDWARD F. MOODY then read the paper of the evening, on "The Channel of the Delaware River at Philadelphia." The paper gave an account of the past condition of the river channel, as shown from fragments of history, old surveys, etc.; dwelt upon the gradual filling up of the Philadelphia side of the channel, the causes and possible consequences thereof; and described the dyke now in course of construction at Fisher's Point above Petty's Island, under the direction of the Government engineers, as the most effectual means of checking the silting up of the Philadelphia channel, and of securing and maintaining a depth of channel required for the present and future commercial needs of the city. The paper was discussed by Messrs. Tatham, Sellers, Orr, Houston, and others, and has been referred for publication in the JOURNAL.

Adjourned.

WM. H. WAHL, *Secretary*.

BOOK NOTICE.

TUNNELLING UNDER THE HUDSON RIVER: Being a Description of the Obstacles Encountered, the Experienced Gained, the Success Achieved and the Plans Finally Adopted for Rapid and Economical Prosecution of the Work. By S. D. V. Burr, A. M. (Illustrated by working drawings of all details. Twenty-seven plates.) New York: John Willy & Sons, 15 Astor Place. 1885.

The announcement of "A Description of the Obstacles Encountered, the Experienced Gained, the Success Achieved and the Plans Finally Adopted

for Rapid and Economical Prosecution of the Work," comes to those who have followed the rise and progress of the tunnel under the Hudson River, like a promise of fulfilment of long desired knowledge from an authoritative standpoint. The careful and interested reader of what Mr. Burr has written cannot fail to be disappointed in the results of *his* work; ambiguous description and lack of perspicuity in style, leave the reader with very uncertain impressions upon methods and details about which he naturally expected at least clearness enough to permit the conclusion that he understood what Mr. Burr attempts to describe. The value of the book should consist in leaving the reader in possession of all the writer had seen, and in this it too frequently fails.

To one who had visited the work while it was in progress, Mr. Burr's description would probably be clear, but his manner of writing lacks just that perspicuity which is requisite to convey to the otherwise uninformed reader clear impressions and ideas of what is described.

If it was necessary to place the only description of the character of the material through which the tunnel was driven, near the end of the book, it would have been wise to suggest in the preface that Chapter VII might with great advantage be read earlier in the work.

In general terms, it is of great value to know just what degree of success was obtained in driving a tunnel through such material as forms the approaches and bed of the Hudson River at the site of the tunnel; this is naturally established by the existing work done, beyond this simple text the descriptions in question are often unsatisfactory. The engineer can generally gather as much valuable information from a recital of failures as from a statement of successes, and, while it may require a large measure of heroism to give the public the former, it is none the less desirable that the historian should do so. Mr. Burr has hardly met this requirement. As a whole, the book is of value in being the only connected history which so far has been written of the work, but it is to be hoped that the completion of the tunnel will be followed by a more complete and pains-taking narrative which shall supply the defects which seem to belong to the present book. L. Y. S.

NEW MAP OF THE SOLAR SPECTRUM.—Thollon has presented to the French Academy a map of about one-third of the prismatic spectrum, which was constructed at the Nice observatory after four years of assiduous labor. It is more than ten meters long and contains 3,200 lines, or twice as many as are given in Angström's atlas. The chart is divided into four bands, No. 1 giving the spectrum when the sun is 80° from the zenith, and for a mean hygrometric condition of the atmosphere; No. 2, when the sun is 60° from the zenith and the air is very moist; No. 3, for the same zenith distance and a very dry air; No. 4 gives the pure solar spectrum which would be obtained if one could observe outside of the atmosphere. This arrangement enables one readily to recognize all the telluric bands, and also to distinguish those which come from constant elements from those which are due to the variable elements of the atmosphere.—*Comptes Rendus, Sept. 7, 1885.*